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# Paleoecology, Stratigraphy, and Taxonomy of the Foraminifera of the Weches Formation of East Texas and the Cane River Formation of Louisiana.

Haeung Choung

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PALEOECOLOGY, STRATIGRAPHY, AND TAXONOMY  
OF THE FORAMINIFERA OF THE WECHES FORMATION  
OF EAST TEXAS AND THE CANE RIVER FORMATION  
OF LOUISIANA.

The Louisiana State University, and Agricultural  
and Mechanical College, Ph.D., 1975  
Geology

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Paleoecology, Stratigraphy, and Taxonomy of the  
Foraminifera of the Weches Formation of East  
Texas and the Cane River Formation of Louisiana

A DISSERTATION

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Doctor of Philosophy

in

The Department of Geology

by  
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May, 1975

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## ABSTRACT

The Cane River and Weches Formations, consisted mainly of clay and glauconite, were deposited during the transgressive period in the Claiborne Stage of Eocene.

The study of Foraminifera, partially aided by some statistical analysis, and other microfaunas indicates that there are differences in the environment of deposition and stratigraphic relationship between the Weches and Cane River Formations. Comparison between the ecologic characteristics of living Foraminifera and the fossil fauna suggests that the paleoenvironments of deposition of both the Weches and Cane River Formations range from transitional to outer neritic environments. Inferred environment of the Cane River Formation ranges from middle to outer neritic environment. The Weches has been mostly under inner neritic environment.

Foraminiferal assemblages of transitional environment, represented predominantly by arenaceous species, occur in the chocolate brown clay which indicates the initial stage of transgression and beginning of regression. Normal marine Foraminifera are mostly found in the glauconitic and calcareous sediments which constitute major part of the both formations.

Paleoecologic study has resulted in the following environmental evaluation of some of major Claiborne

foraminiferal genera; *Ammobaculites*, *Bolivina* and *Brizalina*, *Bulimina*, *Cibicidina*, *Haplophragmoides*, *Lenticulina*, *Quiqueloculina*, *Spiroplectamina*, *Trifarina*, and *Uvigerina* seem to have remained in the similar environment since the Eocene; *Lamarckina* seems to have adopted shallower environment; *Asterigerina*, *Cibicides*, *Cyclamina*, *Discorbis*, *Gyroldinoides*, *Melonis*, *Neoeponides*, *Siphonina*, and *Trochammina* have adopted deeper environment.

Although the Weches and Cane River Formations show great similarities in the type of sediments, faunal contents and stratigraphic setting, the mode of occurrence and the continuity of some important fauna are interpreted that the Cane River and Weches environments had been separated by time and physical barrier at least in the outcrop area, for which tectonic event which resulted in the deposition of the Queen City Formation in Texas may be partially responsible.

The species of Genus Discorbis and Family Miliolidae, which are extremely abundant and widely distributed in the Weches Formation are absent in the Cane River Formation examined. Stratigraphically significant oyster species, Cubitostra lisbonensis occurs in different horizons of the Weches and Cane River, and C. smithvillensis is absent in the Cane River Formation. Discocyclina advena, conspicuous in the Cane River, is known to occur in the Reklaw Formation; but not present in the Weches Formation.

It is proposed here that the Cane River Formation is lithostratigraphically continuous only with the Reklaw Formation of East Texas. The Weches and the Reklaw Formations are not considered to merge to form a single unit, equivalent to the Cane River Formation, in the vicinity of south of the Sabine Uplift.

As a result of taxonomic reexamination of Foraminifera 144 species of 72 genera are described including 4 new species and one new subspecies. A total of 48 species which were originally described as new species from the Cane River Formation are identified as synonyms of previously described species.



Paleoecology, Stratigraphy and Taxonomy of the  
Foraminifera of the Weches Formation of East Texas  
and the Cane River Formation of Louisiana

INTRODUCTION

The Claiborne of the Gulf Coast Eocene Epoch has been the subject of numerous paleontological and stratigraphical studies. Its abundant fossils and fortuitous position in the Tertiary sequence made the Claiborne the focal point in regional studies when the geology of the Gulf Coastal Plain was being unraveled. In view of the fact that much of the original work done was of a local nature, it was difficult, at first, to blend the many independent interpretations and conclusions into a comprehensive whole, in the fields of both paleontology and stratigraphy. Stratigraphers had difficulty recognizing each other's lithologic units; paleontologists had not thoroughly resolved the taxonomy of the faunas, and gave no consideration to the fact that many faunas were controlled by facies.

Shaw (1964) pointed out that with the advent of highly sophisticated geological techniques, the application of paleontology as the measure of time and spatial relationship between the sedimentary units has often been replaced by the traceable lithic units, especially in the field of applied geology. Paleontological data are sought in many instances and areas only when the lithic units fail to be evident. In some areas, paleontology has become a field in which complex

nomenclatural studies are conducted without due consideration for what the organisms reveal from an ecological standpoint.

Recently the importance of paleoecology in understanding the history of sedimentary sequence has been emphasized and numerous studies in both the fields of ecology and paleoecology have been published. A few studies of foraminiferal paleoecology, based on some criteria obtained from living organisms, have proven to be useful and reliable in both paleoenvironmental and stratigraphic studies. However, these studies are based on observations in relatively younger sections. The feasibility of applying recent criteria to the older geologic units (generally older than Oligocene) remains to be tested.

It is the goal in the present study to present a technique which will result in some useful method in future research in the use of Foraminifera in paleoecology and applied paleontology. The Weches Formation and the Cane River Formation were chosen for this study because the relationship between the two formations has been rather elusive. Although closely located, with similar lithologic and paleontologic content, their relationship was not clearly understood.

Reports by Wendlandt and Knebel (1928), Ellisor (1929), Plummer (1933), and Stenzel (1938) contributed materially to formulating the stratigraphy of the Weches in the Claiborne Group, the paleontology of which has been the subject of numerous studies especially with Foraminifera. The Cane

River foraminifera, however, has only been reported in two monography. The two formations have been loosely correlated on the basis of their distinctive lithology and a few molluscan species; however, their lateral traceability has never been seriously tested. Because the previous publications on Foraminifera have been completed with no intention of comparing the two formations, the taxonomic differences have not been resolved. Consequently, revision of the taxonomy was bound to be inherited by anyone who attempted to use Foraminifera in comparing the two formations from biostratigraphic and paleoecologic standpoints.

The main objective of this study, therefore, is twofold:

- 1) to reexamine and redescribe the Cane River and Weches Foraminifera.
- 2) to analyze paleontologic data for paleoecologic and stratigraphic comparison leading to a new interpretation of the relationship between the two formations.

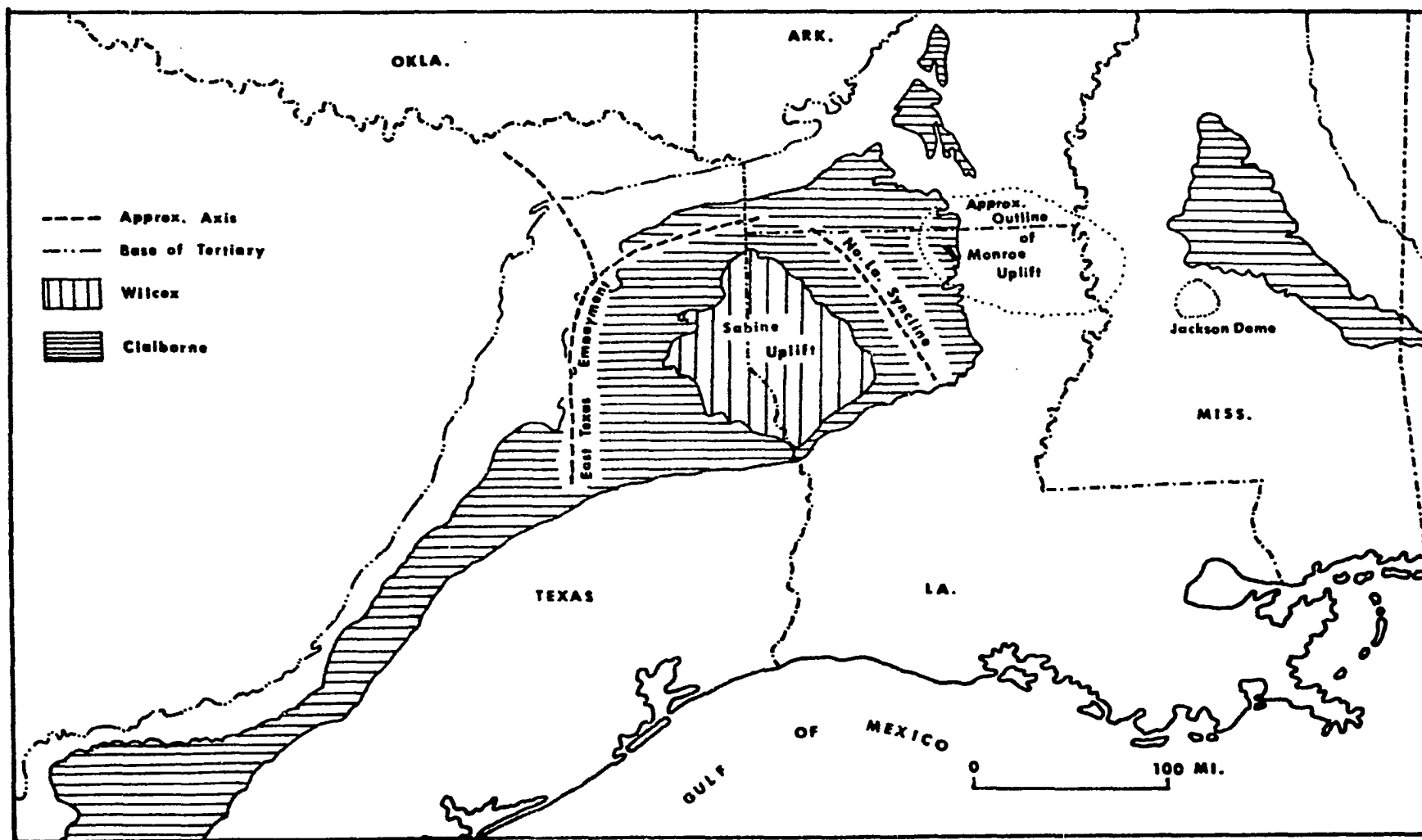


Fig. 1. Distribution of the Claiborne Group and Related Structural Elements  
(After Blanfield 1960, Murray 1957, Sellards et al 1932, Geol. Map of U.S.)

## PART I. PALEOECOLOGY AND STRATIGRAPHY

### GEOLOGICAL SETTING OF THE AREA STUDIED

#### Structural Elements

##### East Texas Embayment

This negative area has been in existence at least since the Jurassic or Pre-Jurassic and has grown progressively to receive a thick sedimentary sequence (Barrow, 1953; Coon, 1956). The embayment has generally a North-South axis to the West of the Sabine Uplift and bifurcates northeasterly to the North of the Sabine Uplift and northwesterly to the front of the Ouachita fold belts (Longwell et al, 1954). The Northeastern extension of the basin was connected with the North Louisiana syncline north of the Sabine Uplift. The northwestern extension was not a prominent feature at the time of Claiborne deposition (Geologic Map of the U.S., USGS.).

The shape of the basin was modified, as the center of the Sabine Uplift shifted eastward in the Jurassic and early Cretaceous. Later sedimentary sequences were deposited in the basin approximately at the present axis as the easterly shifting of the Uplift was stabilized in the early Tertiary (Murray, 1961). Except in Cretaceous time, when the Southern part of the basin is thought to have been constricted by some positive elements, the embayment was open to the Gulf

geosyncline proper. The marine environment receded from the area after extensive deposition of the Claiborne Group.

Within the basin numerous salt domes controlled the positive and negative elements to a minor scale.

### Sabine Uplift

The Sabine Uplift, first recognized by Harris (1910), is a broad platform generally outlined by the Wilcox-Claiborne contact with the oldest sediments exposed being of Midwayan age.

The Uplift is approximately eighty miles long and sixty-five miles wide (Murray, 1961) and has numerous structural features which served as hydrocarbon traps. The center of maximum uplift shifted eastward during late Coahuilan and early Commanchean and has remained in the present area since then. The Sabine Uplift is thought to have been a positive element since as early as late Paleozoic-early Mesozoic time, as evidenced by the absence of salt deposits, and reflects the rejuvenation of the basement or topographic relief. The Uplift might have been the largest offshore landmass in the Gulf of Mexico during the lower Claiborne.

There are a number of hypotheses as to the origin of the Sabine Uplift including igneous intrusion (Moody, 1931), and differential tectonic rejuvenation of the Wichita trend (Murray, 1961). However, the cause of the Uplift is not well understood.

### North Louisiana Syncline

The North Louisiana Syncline trend northwest-southeast

in north Louisiana and encircles the Sabine Uplift on the northern side and connects to the northeastern extension of East Texas Embayment (Longwell et al, 1954). Subsurface contours, based on the Lower Cretaceous beds, show a somewhat wedge-shaped embayment between the Sabine Uplift and the Monroe Uplift (Williamson, 1959). Prior to the Lower Cretaceous, the syncline was a broad irregular sedimentary basin with the center of the Sabine Uplift farther to the west. Later the axis of the syncline was modified by the growth of the Sabine and Monroe Uplifts without any structural compression. There are a number of salt related structures indicating the existence of the basin in Jurassic or an earlier time and they form major structural features within the basin (Murray, 1961). The Monroe Uplift remained submerged during most of the early Tertiary and a normal sedimentary sequence of the Eocene is found on its top. It has been mainly a submarine feature to the northeast of the North Louisiana syncline without significant environmental control over the sedimentation of Claiborne time.

#### Areal Distribution of the Claiborne Group

The total thickness and areal disposition of the Claiborne Group varies from place to place in surface exposure with individual formations ranging from a few feet to several hundred feet in thickness. Some formations of the group occur in a belt of several miles while some are too thin to be mapped even in a relatively large-scale map.

The group extends southwest to northeast from the Mississippi embayment to the northeastern part of Mexico, Outcrops are completely lacking in the Mississippi alluvial belt. Around the Sabine Uplift, its strike conforms to the general outline of the Uplift. North and west of the Sabine Uplift all of the formations have relatively wide areal extent and can be traced into North Louisiana. South of the Sabine Uplift, the surface exposures of the Carrizo, Reklaw, Queen City and Weches formations, however, converge into a very narrow belt. Only the Reklaw and/or Weches are exposed in a band of less than half mile wide near the Sabine River and can not be traced into Louisiana.

These Claiborne formations are well recognized in Texas, but not clearly recognized in Louisiana.

### Regional Stratigraphy

Early Tertiary units in the Gulf Coast area are composed entirely of arenaceous sediments which separate carbonates of the Cretaceous and calcareous clay and argillaceous sediments of later periods in the early Tertiary. The Claiborne formations show a transitional nature between those predominantly arenaceous facies and argillaceous facies with a variety of sediments and environments.

The Claiborne group in the area studies consists of interfingering marine and non-marine units of glauconite, sand, silt, clay and marl generally in a cyclic sequence comprising the beds between the Wilcox and the Jackson Group. Stenzel (1941) characterized this sequence as having a cycle



of "Cross-bedded sand (Regressive hiatus)" and "Basal glauconite (Transgressive hiatus)" from their apparent physical break and the slowness of deposition. Generally, the terrigenous source was not active during the marine transgression resulting in relatively thin authigenic sediments. In most cases of non-marine sedimentation, rapid dispersion of deltaic or fluvial sediments constructed rather thick clastic units and often preserved transitional contacts between marine and non-marine units. Therefore, it is suspected that the cyclic deposition was controlled by the rejuvenation of the source area and not by the eustatic change of sea level.

As all units show considerable lateral persistence, each Claiborne unit has sometimes been thought to have been deposited in a single continuous environment. Although major types of sediments and depositional environments remained in similar conditions in each cycle, there are a great variety of environmental and stratigraphic settings within and between lithic units. The following table shows a summarized correlation between the Claiborne units in the area accepted by most Gulf Coastal geologists. The table was freely drawn from various sources. Their histories and validity will not be discussed except for those directly concerned with the present study.

#### Carrizo Sand

There are some reservations as to the exact position of the Carrizo Sand in the Wilcox-Claiborne stage because of

	Texas		Louisiana	Mississippi	W. Alabama
	Formation	Member	Formation	Formation	Formation
Jackson					
..? ..	Yegua - Cockfield		Cockfield	Cockfield	Gosport Sand
	Cook Mt.		Cook Mt.	Cook Mt.	Lisbon
			Sparta	Sparta	
	Weches	Therill Viesca Tyus	? Cane River ? ? ?	Zilpha Clay	
	Queen City	Mytris Omen Arp		Winnona Sand	
	Reklaw	Marquez Newby		Neshoba Sand Tallahata	Tallahata
	Carrizo				
			? Carrizo		
Wilcox					

Table 1. Claiborne Formations of East Texas, Louisiana, Mississippi, and West Alabama. (Modified after Durham et al 1960, Moody 1931, Murray 1961, Toulmin 1967, Stenzel 1939, Williams 1959)

its unconformable contact with the lower lignitic Wilcox and the overlying Reklaw. Originally separated from the Wilcox by Owen (1888) to include all sand layers between the lignitic shale below and the glauconitic clay of the overlying Reklaw Formation, it is a product of a variety of transitional environments (Davis and Ethridge, 1971) consisting of a massive layer of stratified, cross-bedded, fine to medium grained clean sand. Locally some light colored clay and volcanic ash are present and in placed sediments are indurated into a hard ferruginous sandstone.

In Louisiana, the Carrizo is restricted to a narrow belt around the outer margin of the Sabine Uplift where it is differentiated from the Upper Wilcox. Generally, the surface exposure is limited, and in most places it is not clearly separated from the Wilcox. However, in many subsurface wells it has been observed that the overlying Cane River maintains transitional contact with the undifferentiated upper Wilcox which is thought to be the Carrizo equivalent. This seems to correspond to the nature of the gradational boundary between the Carrizo Sand and the Reklaw in Texas where contacts between the two formations could be observed in outcrops.

#### Reklaw Formation

Originally designated as a member of the Mount Selman Formation in Texas (Wendlandt and Knebel, 1929), later raised to formational rank (Plummer, 1933) and subsequently subdivided into two members (Stenzel, 1939), the Reklaw

Formation includes basal glauconitic sand and upper glauconitic and brown clay with streaks of glauconite or sand below the Queen City sand. The Lower Newby member consists of alternating glauconitic sand, glauconitic brownish shale and some brown clayey ironstone.

In east Texas the lower contact is marked by the dark glauconitic bed at the base of the formation separated from the brown to dark blue micaceous sand member of the upper Carrizo by a locally continuous unconformity. The glauconite was initially included in the Reklaw but separated later from it (Stenzel, 1950). In places this bed has been observed to contain larger numbers of Venericardia planicosta Lamarck and Turritella turneri Plummer. Stenzel (1948) recognized this as a lagoonal facies occurring in the northern part of the Tyler basin (Northern East Texas Embayment). He also recognized a marine facies of the same horizon with rich and varied fauna in the southern end of the basin. One noteworthy observation in the Newby member is the finding of typical Cane River Foraminifer Discocyclina advena from the test wells of Simm's Renfro No. 1 in Angelina County and Southern Pine No. 1-A in Trinity County, Texas (Ellisor, 1920). Because of this, Ellisor mistakenly identified those subsurface sections of about fifty feet as the Cane River Formation. The upper member of the Reklaw formation, the Marquez shale, is mainly composed of chocolate brown, locally calcareous, clay grading into the Newby glauconite. The boundary between the

two members is therefore placed on the basis of predominance of the constituent elements. The total thickness of the Reklaw in East Texas varies from 30 to 130 feet. Until now, the Reklaw was thought to be strictly a Texas unit often correlated with the lower part of the Cane River of Louisiana.

#### Queen City Formation

Named by Kennedy (1892), the Queen City Formation is a complex deltaic system commonly divided into three members in East Texas and North Louisiana; an upper Mytris sand member (Smith, 1958), middle Omen member of Glauconite (Wendlandt and Knebel, 1929), and lower Arp sand member (Moody, 1931). The Queen City Formation contains a series of sediments usually associated with constructive and destructive deltaic sequences ranging from lignitic clay to clean blanket sand. In Texas it has been noted that the Queen City sand in the outcrop belt piches out toward the east and disappears in the east of San Augustine County (Dzilsky, 1953; Ellisor, 1929) where the Weches above and the Reklaw below are thought to merge, forming a single continuous section equivalent to the Cane River of Louisiana. There is a new interpretation on such thinning and disappearing of the Queen City in East Texas, which will be discussed later in the chapter of stratigraphy. North of the Sabine Uplift in Caddo Parish, Louisiana, Smith (1958) recognized all three members of the Queen City which has a total thickness of 118 to 165 feet, and noted that these members were

traceable as far as into the east bank of the Red River in Bossier Parish. However, the relationship of the Queen City Formation with adjacent formations was not clarified. It is interesting to note that within the Queen City there was a brief marine transgression even up to this area contrary to the most common opinion that the Queen City Sand is a product of a single event of deltaic propagation.

### Weches Formation

Wendlandt and Knebel (1929) designated the Weches originally as a member of Mount Selmen Formation which, in East Texas, consisted of brown clay, olive green to blueish green glauconite, and glauconitic marl of varying thickness ranging from 50 to 150 feet in Texas. Stenzel (1938), from his observation in Leon County, Texas, subdivided the Weches into three members recognizing gradational contacts between them. This subdivision is in common use by many surface geologists although this three-fold division is not readily apparent in many places. The Therill, the upper member, consists of chocolate brown clay which Stenzel (1952) described as a continuous unit which extends as far as Mississippi where it correlates with the Zilpha Clay. Stenzel further suggested that the Zilpha be suppressed and replaced by Therill.

The middle member, the Viesca, is the most conspicuous unit in the Weches. It consists predominantly of poorly bedded bluish-green glauconite and glauconitic marl with a rich fossil fauna.

In the East Texas area the lithology of the lower Tyus member appears to be different from what has been described in the type section where it is commonly known as light colored "Salt and pepper" textured calcareous marl. In most of the outcrops and cores studied, the lower member shows lithic characteristics similar to the upper Therill. It consists of chocolate brown clay and alternation of glauconite and brown clay. Lime nodules and limestone benches are more abundant in this section. Generally, the total thickness increases slightly toward Nacagdoches and San Augustine County and to the Northeast toward the northwest of the Sabine Uplift. Particularly, in Cass County, the Weches "green-sand" becomes more sandy and is cross-bedded. Iron ore occurs irregularly in the upper section of the Weches in this area. This, compared with other normal sequences of the Weches sediments in the South and Southwest margin of the Sabine Uplift, indicates the closeness of the terrigenous source area and the relatively insignificant role of the Sabine Uplift as a source area although it remained as a positive element throughout the Claiborne.

Boundaries between the Weches and adjacent formations are often problematic. As the Queen City sand is a product of multi-sedimentary facies, the Weches-Queen City boundary is also controlled by laterally shifting environmental conditions. Generally, the lower contact is conformable in the southern part of the Weches basin and disconformable in the northern part of the area where the Queen City becomes

sandier and cleaner. However, in the eastern part of Texas where the Queen City sand thins out, the relationship between the Weches and Reklaw is not well established. The upper contact with the Sparta appears to be transitional in most places as the Sparta sand quickly spread over the receding marine environment of the Weches.

#### Cane River Formation

Spooner (1926) named the series of chocolate brown clay, glauconite, and glauconitic marl in Natchitoches Parish, Louisiana, as the Cane River Formation at the suggestion of H. V. Howe. The thickness varies, averaging from 75 to 150 feet in the vicinity of the type locality, but generally increases away from the Sabine Uplift toward the east and southeast up to 300 feet in the subsurface. The sediments consist of upper chocolate brown clay and lower glauconite and glauconitic marl. In the Southeastern part of the outcrop area the lower glauconitic section becomes more marly with scattered glauconites commonly logged as "salt and pepper" texture.

To the east of the Sabine Uplift the strike changes from NE-SW to NW-SE and the sediments become sandier toward the north and northeast part of the uplift. In Bossier Parish it was observed that the Cane River consists entirely of sand with little glauconite (Spooner, 1926). However, in Webster Parish to the east the lithology maintains its usual sequence as in the type section, indicating deepening of the



basin or remoteness from the clastic source. There was an attempt to subdivide the Cane River into two members of the upper clay and lower marl (Shearer, 1930) and later the lower part of the Sparta was added as an uppermost third member (Chawner, 1936). However, this kind of subdivision is not reasonably applicable to the entire Cane River Formation.

In the area studied, the formational boundaries appear to be conformable as observed in a few shallow cores where the entire section could be examined. The lower contact with undifferentiated Wilcox is typified by the presence of unfossiliferous brownish quartzose sand with some glauconite which resembles the Reklaw-Carrizo relationship in Texas.

### Sparta Sand

The Sparta Sand, first introduced by Vaughan (1876) from North Louisiana and amended by Spooner (1926) now includes loose, massive, well-bedded, buff to yellowish orange sand with transitional light grayish silty clays notably in the zone of stratigraphic contacts with neighboring formations. These transitional clays posed some uncertainty as to the formational boundaries with Cook Mountain Formation above and the Weches and Cane River below.

In East Texas the Sparta contact with the underlying Therill member of the Weches is observed to be disconformable in Leon County and Houston County (Stenzel, 1938) but more transitional toward the east. This transitional nature is more apparent in Sabine and Natchitoches Parishes, Louisiana.

where light gray, reddish mottled, sandy clay grades into chocolate brown clay of the upper Cane River.

The upper boundary described from wells and outcrops shows a more or less similar transitional relationship as the lower contact. If the Sparta sand were to be strictly defined as the sand mass between clays above and below, the total thickness would be reduced considerably. On the other hand, if it should include all non-fossiliferous clays, the thickness would increase and boundaries can only be decided paleontologically. The latter is possible and reasonable because the adjacent formations are supposed to be the product of marine transgression. Therefore, any indication of marine environment by fossil fauna should establish the boundary between marine and non-marine formations where the contact is transitionally conformable. The total thickness ranges from 150 to 500 feet with Louisiana sections being generally thicker.

## Lithology of the Formations Studied

The lithology of the Weches and Cane River Formations shows great similarity in both sediment types and sequence in the section. The sediments consist of glauconite, glauconitic marl, clay, sand, and calcareous organic remains. Of these, glauconite and clay are the main constituents. Subordinate elements are iron concretions and nodules derived from siderite and glauconite, abundant in the Weches, rare in the Cane River. The minor clastics in the sediments of both formations consist of medium to very fine, poorly sorted, subangular quartz sand grains.

There is great variation of the glauconite in size, shape, and color of the individual grains. The size ranges from clay to coarse sand size particles; the shapes are irregularly "lumpy" to peletized; and the color varies from dark bluish green to yellow or olive green. The environmental and paleoecological significance of these physical characteristics of glauconite occurring in the sections examined were not evaluated because such a study was not considered to be within the scope of this investigation.

The distribution of clay appears to be environmentally controlled. Chocolate brown clays, generally fossiliferous, ordinarily contain foraminiferal assemblages of the shallower transitional zone. The light gray clays are more silty and non-fossiliferous, usually grading upward into more sandy beds in the lower part of the Sparta Formation considered to be of continental origin.

Miscellaneous elements in the sediments are limestone, which varies from nodules to laterally persistent beds in which the sediment present is cemented into concretionary benches, concentrations of oyster shells forming "oyster banks", and carbonaceous materials which are confined to the upper clay section in both formations.

Trace fossils are abundantly present in the Weches Formation; if present in the Cane River Formation, they were not apparent in the outcrops examined or the cores obtained from the subsurface.

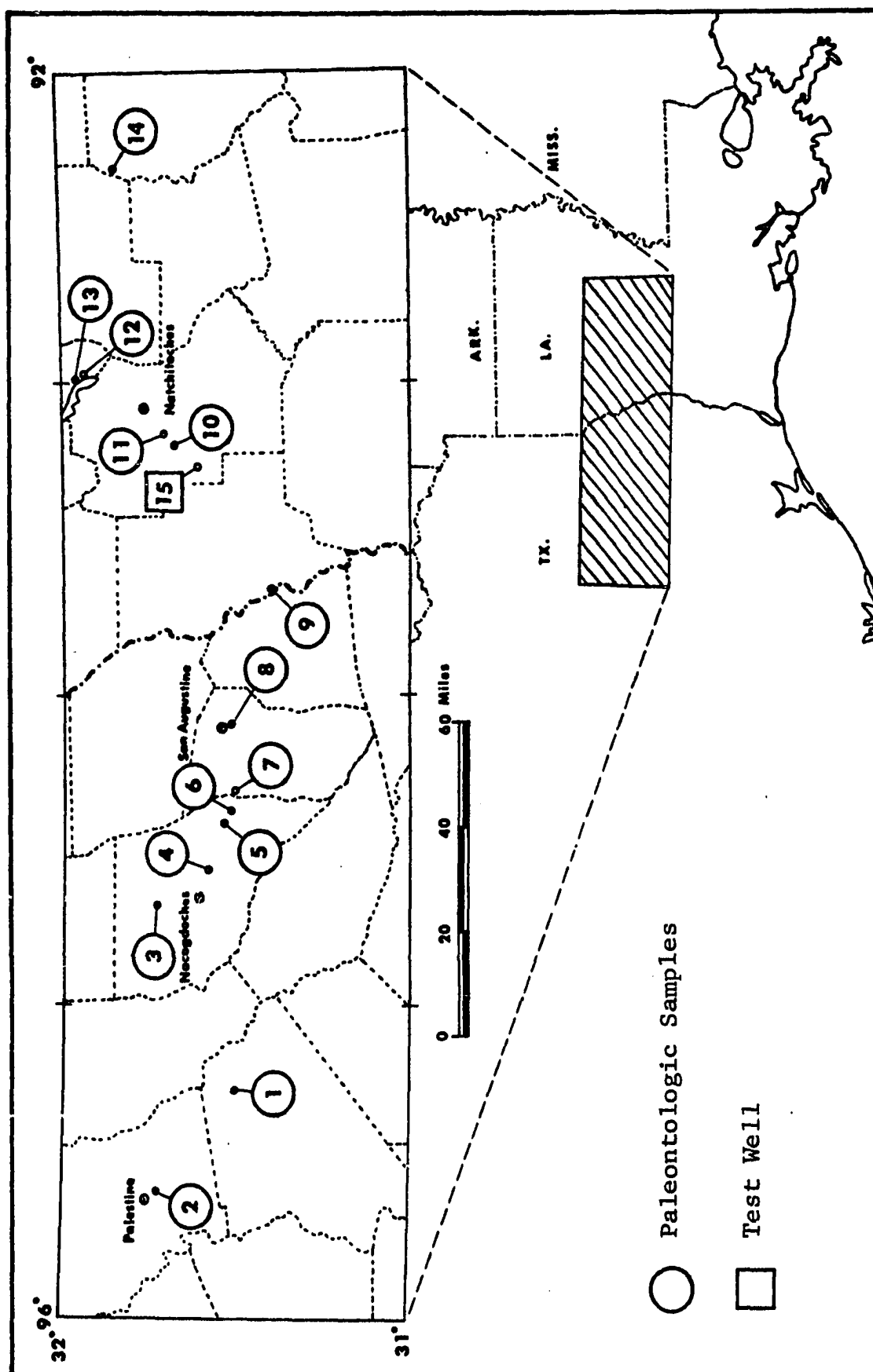


Fig. 2. Sample Localities

## List of Localities

## 1. Weches, Houston County, Texas (core)

N 31 29' 50"

W 95 16' 10"

2.5 miles southwest from the intersection of Texas  
21 and 227 on Texas 21

## 2. Palestine, Anderson County, Texas

N 21 41' 30"

W 95 35' 10"

4 miles south of Palestine on Highway 287

## 3. Nacagdoches, Nacogdoches County, Texas

N 31 43' 30"

W 94 40' 45"

2 miles south of the intersection of Texas 204  
and 26

## 4. Bayou Carrizo, Nacogdoches County, Texas

N 31 34' 30"

W 94 33' 15"

0.5 mile east of the bridge over Bayou Carrizo on  
Texas 21 and Loop 34

## 5. Chireno II, Nacogdoches County, Texas

N 31 31' 50"

W 94 24' 30"

4.8 miles west of the intersection of Texas 21 and  
Loop 34

6. Chireno, Nacagdoches County, Texas  
     N 21 30' 20"  
     W 94 21' 00"  
     At the intersection of Texas 21 and 34
7. Bayou Attoyac, San Augustine, Texas  
     N 31 30' 15"  
     W 94 18' 00"  
     0.5 mile east of Bayou Attoyac on Texas 21
8. San Augustine, San Augustine County, Texas  
     N 31 29' 50"  
     W 94 6' 30"  
     2.5 miles south of the intersection of Texas 21  
         and San Augustine - Chinquapin county road
9. Bayou Negreet, Sabine Parish, Louisiana  
     At the south of mouth of Bayou Negreet.  
     Sections are now submerged because of the construction of Toledo Dam  
     SW $\frac{1}{4}$  of Sec. 23, T5N, R2W, Sabine Parish
10. Provencal, Natchitoches Parish, Louisiana  
     1 mile northeast of Provencal on Provencal-Hagewood Road
11. Hagewood, Natchitoches Parish, Louisiana  
     Exposure on the upstream of Limekiln Bayou  
     NE $\frac{1}{4}$  of Sec. 3, T8N, R8W, Natchitoches Parish

12. Clear Lake II, Natchitoches Parish, Louisiana  
Exposure on the northeast bank of Clear Lake  
SW $\frac{1}{4}$  of Sec. 28, T11N, R5W, Natchitoches Parish
13. Clear Lake, Natchitoches Parish, Louisiana  
Exposure on the northeast bank of Clear Lake  
SW $\frac{1}{4}$  of Sec. 28, T11N, R5W, Natchitoches Parish
14. La. Oil and Ref. Co., Tremont No. 2, La Salle Parish,  
Louisiana  
SW $\frac{1}{4}$  of Sec. 29, T10N, R2E, La Salle Parish
15. Robeline, Natchitoches Parish, Louisiana  
SE $\frac{1}{4}$  of NW $\frac{1}{4}$  of Sec. 34, T8N, R9W, Natchitoches  
Parish



## METHOD OF STUDY

### Sample Localities

A total of 15 outcrops and cores were examined in Texas and Louisiana ranging from Anderson County, Texas, to La Salle Parish, Louisiana. The area covered is approximately two hundred miles wide (see Fig. 1). Eleven outcrop sections were measured and sampled and four wells were drilled and cored for the present study. The samples from Bayou Negreet (Location No. 9), now under Toledo Bend Lake, were collected by A. M. Phillips and L. G. Nichols of Louisiana State University in 1966. The prepared samples of Louisiana Oil and Refining Company's Tremont No. 2 cores (Location No. 14) were obtained from the H. V. Howe collection.

Most outcrops were badly weathered because they are composed mainly of unconsolidated sediments. The clay and some glauconite units were usually depleted of fossils because of the leaching effects of ground water on the calcareous shells.

### Sampling Method and Laboratory Preparation

In surface sampling, attempts were made to collect samples at regular intervals where the lithology was consistent. This system of sampling was disregarded whenever there was a change in lithology or sedimentary structure. About one to two kilograms of sample was collected from a one-foot channel wherever possible, otherwise a grab sample

from the available section was collected.

Coring operations were carried out with an ARCO PORTABLE DRILLING UNIT (MODEL AR-550-DD) by the Louisiana Geological Survey. Sample intervals from cores could not be controlled because of the nature of the sediment and the sampling device employed.

In addition to the samples collected by the author, four samples of glauconitic clay from Bayou Negreet, which were previously collected for the Museum of Geoscience of Louisiana State University, were incorporated in the present study. Twenty-two prepared slides of Foraminifera from the core samples from La Salle Parish, Louisiana, were also used for taxonomic reference and stratigraphic evaluation.

The final group of samples used for the paleontologic observations were unnumerically coded in five digit numbers: the first digit represents the State; the second and third, the sample locality; and the fourth and fifth, the depth at which sample was collected. A "0" was added when the sample locality and sample depth was less than "10". For example: Sample No. 10125 shows that the sample was collected in Texas (1) from locality No. 1 (01) at a depth of 25 feet from the top of the section (25).

About 300 grams of sediment was separated from each sample for paleontologic examination. Samples were treated with varsol or sodium bicarbonate depending on the degree of consolidation. Residues were recovered by removing clay fractions with a standard 250 mesh. An arbitrary amount of

sediment was randomly separated from the dried residue for quantitative determination of the microfauna therein. Approximately 200 to 300 specimens of Foraminifera, counted randomly, were considered to be representative of foraminiferal thanatocoenosis. Ostracods, molluscs, and other faunal groups were removed from the residue and evaluated qualitatively.

### Statistical Analysis

The statistical analysis adopted herein is used to detect if there exist any variation in quantitative and qualitative information on foraminiferal taxa with depth and environment. Reliability is largely dependent upon the correct procedure of deriving raw data, minimizing any extraneous error, and the effectiveness of a factor or factors as a source of variation.

Limitations on the death assemblage as the true representative of the biocoenosis and other secondary effect on the experimental data were not taken into consideration. Therefore, the resulting statistics are strictly characteristics of fossil community and may not be a true measure of comparison between death and living assemblages.

### Regression Analysis

The purpose of regression analysis is to isolate the taxa which vary significantly with depth. As discussed in the summary of ecologic factors, depth is the only tangible source of variation which can be isolated and sampled in a

controlled study. For the time being, therefore, the depth may be the only factor which can be applied to the paleo-ecologic purpose because it is still the only reliable source of variation in the recent environments which effectively summarizes the ecologic distribution of the organism, especially Foraminifera.

A stepwise maximum  $R^2$  (Coefficient of determination) procedure (Barr and Goodnight, Statistical Analysis System, 1972) was employed to determine the best component (singly, double, triple, quadruple) model for each taxon. The highest order polynomial model, in which each coefficient was significant at the 5% and 10% level, was selected. Equation based on the regression model was graphically presented as a prediction trend of a taxon.

The model adopted for the present study includes the depth factor with linear, quadratic, cubic and biquadratic effects of depth. This would show the type of frequency variation of a taxon in a series of samples (depth) if the frequency of a taxon is controlled by depth. However, this prediction trend is only a best fitting model within a given order for the measured frequency trend of a taxon and may not account for smaller fluctuation of the data. But this is still considered to be sufficient to show major trend with the depth. The general regression equation can be expressed as follows:

$$Y_i = b_0 + b_1 X_i + b_2 X_i^2 + b_3 X_i^3 + b_4 X_i^4 + E_i$$

Where  $Y_i$  is the relative frequency of a concerned taxon,

$b_0$  is the relative frequency at  $X_i = 0$ ,

$b_1, b_2, b_3, b_4$  are the partial regression coefficients  
for  $X, X^2, X^3, X^4$ , respectively,

$X_i$  is the  $i^{\text{th}}$  depth within the section,

$X_i^2$  is the  $i^{\text{th}}$  depth squared,

$X_i^3$  is the  $i^{\text{th}}$  depth cubed,

$X_i^4$  is the  $i^{\text{th}}$  depth to the 4th power,

$E_i$  is the error term which is assumed to be randomly  
and normally distributed about a mean of zero  
with a common variance  $NID(0, \sigma^2)$ .

### Cluster Analysis

The objective of cluster analysis is the clustering together of variables which are most highly intercorrelated.

For the present study the Unweighted Pair-Group Method Using Centroid Averaging (UPGMC) was used, which is a type of sequential agglomerative hierarchical cluster analysis. The initial assumption made in such an analysis is that each object constitutes a group (an assemblage or sample for the present study). One begins by having defined for each object pair a set of similarity coefficients based on the predetermined set of observed data. Any two objects may be designated as  $X_i$  and  $X_j$  and between them a similarity coefficient  $S_{ij}$  exists, which reflects the degree of similarity based on the data observed in the object. A series of such a correlation eventually results in a set of  $\frac{n(n-1)}{2}$

pairwise similarity coefficients for a number of objects. Together these coefficients can be arranged in the form of a  $n \times n$  matrix in which  $S$  having the property that  $S_{ij} = S_{ji}$ . This matrix then forms the basis of arranging the set of  $n$  objects into mutually related group.

Detailed discussion on the theoretical nature and mathematical procedures of the analysis is omitted here. A substantial literature exists on the cluster analysis. Its basic application in geological research is well explained by Sokal and Sneath (1963) and Fenner (1969). Computerized mathematical performance of such an analysis is also readily available from many sources.

Output of the analysis was expressed in the form of a dendrogram based on the distance (similarity coefficient) matrix of above pairwise correlations for 114 samples. This dendrogram has a hierarchial configuration in which each level of hierarchy reflects the degree of similarity in the group. However, the degree of similarity (grouping) is subject to arbitrary concept of a group defined by the user of such analysis based on one's particular need. Therefore, in the long run, it can be said that the clustering is inevitably influenced by the user's interpretation of the value of the observed data which are again selective. This type of test has been often used in the field of taxonomy where some systematic similarities exist between the variables. The analysis in the present study was rather experimental, examining the feasibility of such test in the stratigraphy

and paleoecology. Up to now such an attempt has not been made in the study of Foraminifera. Therefore, the effectiveness of the clustering method is not comparable to any other similar studies. The results showed, however, that there is a great potential in the use of this analysis for paleoecologic and biostratigraphic studies.

Following taxa were used for the cluster analysis. The reason for choosing such taxa is explained in the discussion on distribution.

1. Alabamina
2. Anomalinoidea
3. Asterigerina, Asterigerinata
4. Bolivina, Brizalina
5. Bulimina
6. Ceratobulimina
7. Cibicidina
8. Cibicides
9. Discorbis
10. Globocassidulina
11. Globulina
12. Guttulina
13. Gyroidinoidea
14. Lamarckina
15. Lenticulina
16. Neoeponides
17. Siphonina
18. Spiroplectamina
19. Trifarina
20. Uvigerina
21. Lituolidae
22. Miliolidae
23. Planktonic/Total Population Ratio

The same taxa were also used for the regression analysis.

## REPRESENTATIVE FAUNA

### Foraminifera

#### Previous Works

Previous works in foraminiferas from the Weches Formation are mostly taxonomic monographs by Cushman and Thomas (1929, 1930), Cushman and Ellisor (1933), Cushman and Ozawa (1930), Feray (1941, 1948), and Garrett (1942). Feray described the entire Weches Foraminifera for the first time in his unpublished dissertation, and Curtis (1955) attempted a paleoecological interpretation of some foraminiferal species from a single section of the Viesca member of the Weches Formation based on the then available ecologic information related to Foraminifera. As a result of above publications, a total of 91 species have been reported from the Weches Formation.

The Cane River Foraminifera were studied only by Hussey (1943, 1949) in which 90 new species and one new subspecies were described from the 133 species he reported from the Cane River Formation.

#### Distribution

In this study, a quantitative observation of species was made of 114 samples from 13 different localities with 200 to 300 individuals counted from each sample. An additional 22 samples from the H. V. Howe's collection were used for qualitative examination only.



Statistically, a species which constitutes at least 1% of the total population has a 95% probability of being observed in any given sample assemblage consisting of at least 299 individuals. If a species has 2% frequency in the population, only 149 individuals are needed to include the species in the sample assemblage with the same probability. Therefore, it was concluded that a sample of 200 to 300 individuals would reasonably reflect the characteristics of the faunal content of the sample.

In this study, the term sample and assemblage were used synonymously because a faunal assemblage represents the paleontologic property of a sample. In the present study there are 114 quantitative samples representing the same number of foraminiferal assemblages.

The number of individuals observed from each sample varies. This irregularity in sample size affects the diversity of fauna (number of species) proportionally. The general diversity of faunal assemblage increases with increased number of individuals observed. This explains the discrepancy between the diversities of fauna observed in the assemblage prepared for the purpose of quantitative study (less) and qualitative assemblage collected for the purpose taxonomic study and other specific reasons (more) in which usually much more individuals are examined.

Murray (1973, p. 9, fig. 4) attempted to adjust diversity-number of individual relationship among heterogeneous sample sizes by using predicted diversity index.

However, in the Weches and Cane River samples the differences were found to be minor; therefore, readjustment of diversity for the purpose of comparison between the two formations was not made.

When only those "common" species are selected, the total number of species decreases substantially and this in effect represents the true faunal characteristics of a sample assemblage unless there is an unique faunal property in the population marked by a rare but conspicuous taxon or particular combination of taxa.

In the present study of Foraminifera, planktonic species were treated separately because they had no bearing upon the benthic environment except where the variation of their frequency ratio in the total population indirectly suggesting a bathymetric difference. After the ratio of planktonic/total population was calculated in the sample, individual planktonic species, based on occurrence, were recorded.

Following is the list of Foraminifera species and their occurrence in the Weches and Cane River formations.

List of Species and Their Occurrence

	<u>Weches</u>	<u>Cane River</u>
Alabamina wilcoxensis	*p	p
Ammobaculites mauricensis	p	p
Ammobaculoides new sp.		p
Ammodiscus incertus		p
Anomalinoidea ammonoides		p
A. costianus	p	p
A. umbonatus	p	p
Asterigerina texana	p	p
Asterigerinata new sp.	p	p

\*p = present

Weches — Cane River

Bolivina gracilis	p	p
B. louisiana		p
B. cf. plicatella merra	p	p
Brizalina taylori	p	p
Bulimina byramensis	p	p
B. simplex		p
B. truncana aksuatica		p
Ceratobulimina eximia	p	p
Cibicides delicatus		p
C. jeffersonensis	p	p
C. lawi	p	p
C. lucidus		p
C. mamiformis	p	p
C. cf. mimulus	p	p
C. cf. pseudowuellerstorfi	p	p
C. new sp.		p
Cibicidina mauricensis	p	p
C. mississippiensis	p	p
C. hypoconoides	p	p
Cribrostomoides complanata	p	p
Cyclamina cancellata obesa	p	p
Cyclogyra lisbonensis	p	p
Dentalina communis	p	p
D. cf. consobrina		p
D. vertebralis albatrossi		p
Dentalinoides? resupinata		p
Discocyclina advena		p
Discorbis stenzeli	p	p
D. tallahattensis	p	p
D. yeguaensis	p	p
Elphidium new sp.	p	p
Epistominella huneri	p	p
Fissulina obvia		p
F. cf. orbignyana		p
Fursenkoina zetina	p	p
F. mcguirti		p
Globobulimina winniana		p
Globocassidulina globosa	p	p
G. lomitensis mexicana		p
Globulina gibba	p	p
G. inaequalis	p	p
Globulina minuta	p	p
Guttulina irregularis	p	p
G. problema	p	p
Gyroidinoides octocameratus	p	p
Haplophragmoides canariensis	p	p
Hoeglundina eocenica	p	p
Karrerella mauricensis		p
Lagena hispida		p
L. cf. laevis stavensis		p

	<u>Weches</u>	<u>Cane River</u>
<i>L. ouchitaensis alabamensis</i>		p
<i>L. striata strumosa</i>		p
<i>L. sp. A</i>		p
<i>Lamarckina claibornensis</i>	p	p
<i>Lenticulina abuillotensis</i>		p
<i>L. alatolimbata</i>	p	p
<i>L. inhabilis</i>		p
<i>L. kimituensis</i>		p
<i>L. laticostata</i>	p	p
<i>L. mayi</i>	p	p
<i>L. midwayensis</i>	p	p
<i>L. pseudocultrata</i>		p
<i>L. pseudoligostegius</i>		p
<i>L. cf. pseudosecan new subsp.</i>		p
<i>L. stephensoni</i>	p	p
<i>L. velascoensis</i>		p
<i>Loxostomoides nuttalli</i>		p
<i>Marginulina subbullata</i>		p
<i>M. sp.</i>	p	p
<i>Melonis planatus</i>	p	p
<i>M. cf. umblicatula pacifica</i>	p	
<i>Neoeponides mexicanus</i>	p	p
<i>Nodosaria latejugata</i>		p
<i>Nonionella cf. jacksonensis spiralis</i>		p
<i>Nonionellina winniana</i>	p	p
<i>Orthomorphina antillea</i>		p
<i>O. camerani</i>		p
<i>O. delicata</i>		p
<i>Pseudonodosaria conica</i>		p
<i>P. elliptica</i>	p	p
<i>P. cf. ovula</i>		p
<i>P. pleniluna</i>		p
<i>Quinqueloculina sp.</i>	p	p
<i>Q. claiborniana</i>	p	p
<i>Q. danvillensis</i>	p	p
<i>Q. cf. Q. lamarckiana</i>	p	p
<i>Q. cf. leonensis</i>	p	
<i>Q. yeguaensis</i>	p	
<i>Ramulina kittlii</i>		p
<i>R. mariae</i>		p
<i>Robertina plummerae</i>	p	p
<i>Sagina ellisi</i>	p	p
<i>Saracenaria limbata</i>		p
<i>Sigmomorphina jacksonensis</i>	p	p
<i>Siphonides biserialis</i>		p
<i>Siponina claibornensis</i>	p	p
<i>S. danvillensis</i>		p
<i>Siphoninella chambersi</i>		p
<i>S. parva</i>		p
<i>Siphouvigerina elongata</i>		p

	<u>Weches</u>	<u>Cane River</u>
<i>Spiroloculina lamposa</i>		p
<i>Spiroplectamina plummerae</i>		p
<i>S. zapotensis</i>	p	p
<i>Stainforthia eocenica</i>		p
<i>Textularia claibornensis</i>	p	p
<i>Trifarina vicksburgensis</i>	p	p
<i>T. wilcoxensis</i>	p	p
<i>T. new sp.</i>	p	p
<i>Trilogulina paulocostata</i>	p	
<i>T. rotunda</i>	p	
<i>T. trigonula</i>	p	
<i>Tritaxis columbiana</i>		p
<i>Trochammina? sp.</i>	p	p
<i>Turillina robertsi</i>	p	p
<i>Uvigerina blancacostata</i>		p
<i>U. gardnerae</i>	p	p
<i>U. cf. garzaensis</i>	p	p
<i>Vaginulina lineara</i>	p	p
<i>Vaginulinopsis hybrida</i>	p	p
<i>V. mexicanus</i>		p
<i>Globigerina (Subbotina) boweri</i>	p	p
<i>G. gravelli</i>	p	p
<i>G. officialis</i>	p	p
<i>G. cf. officialis</i>	p	p
<i>Globorotalia aequa</i>	p	p
<i>G. (Turborotalia) bullbrookii</i>	p	p
<i>G. (Turborotalia) centalis</i>	p	p
<i>G. compressa</i>	p	p
<i>G. (Turborotalia) mckannai</i>	p	p
<i>G. (Turborotalia) tribulosa</i>	p	p
<i>Chiloguembelina crinita</i>		p
<i>Guembelitria columbiana</i>	p	p
<i>Pseudohastigerina micra</i>	p	p

Summary of Occurrence

	<u>Weches</u>	<u>Cane River</u>
Number of Genera	47	68 (72)*
No. of Species	96	121 (135)
No. of Benthonic Genera	40	61 (65)
No. of Benthonic Species	84	109 (122)
No. of Planktonic Genera	6	7
No. of Planktonic Species	12	13

\* ( ) including non-statistical samples (Tremont Cores)

Commonly occurring species are generally considered to be those species which occur at least by 5% in any sample population. If a species constitutes at least 5% of the total population, it requires only 59 observations (specimens) for the species to be recognized in the sample with 95% probability (Shaw, 1965, p. 109, Table 18-1).

Following are common species thus defined from each formation.

#### Weches

Alabamina wilcoxensis  
 Ammobaculites mauricensis  
 Anomalinoides costianus  
 Asterigerina texana  
 \*Asterigerinata new sp.  
 Ceratobulimina eximia  
 Cibicides lawi  
 C. mamiformis  
 C. cf. pseudowuellerstorfi  
 Cibicidina mauricensis  
 \*Cribrostomoides complanata  
 Cyclammina cancellata obesa  
 \*Discorbis stenzeli  
 \*D. tallahatensis  
 \*D. yeguaensis  
 \*Globulina gibba  
 \*Guttulina irregularis  
 Gyroidinoides octocameratus  
 Lamarckina claibornensis  
 Melonis planatus  
 Neoeponides mexicanus  
 \*Quiqueloculina claiborniana  
 \*Q. yeguaensis  
 Siphonina claibornensis  
 Spiroplectamina zapotensis  
 \*Triloculina paulocostata  
 Trochammina? sp.

Total 22 Genera 27 Species

#### Cane River

Alabamina wilcoxensis  
 Ammobaculites mauricensis

Anomalinoidea costianus  
 Asterigerina texana  
 \*Bolivina gracilis  
 \*Brizalina taylori  
 \*Bulimina truncana aksuatika  
 Ceratobulimina eximia  
 Cibicides lawi  
 C. mamiformis  
 \*C. mimulus  
 C. cf. pseudowuellerstorfi  
 Cibicidina mauricensis  
 \*C. hypoconoides  
 Cyclamina cancellata obesa  
 \*Globocassidulina globosa  
 Gyroidinoides octocameratus  
 \*Haplophragmoides canariensis  
 Lamarckina claibornensis  
 \*Lenticulina alatolimbata  
 \*L. midwayensis  
 Melonis planatus  
 Neoeponides mexicanus  
 Siphonina claibornensis  
 \*S. danvillensis  
 Spiroplectamina zapotensis  
 \*Trifarina new sp.  
 Trochamina? sp.  
 Turillina robertsi  
 \*Uvigerina cf. garzaensis

Total 24 Genera 30 Species

\* Asterics are the species which occur commonly (=5%) only in that Formation.

From these lists it is apparent that each formation is characterized by a group of restricted species which constitute almost half of the commonly occurring species. The meaning of such a distribution is discussed in the chapter on Paleoecology (Page 94).

After examining the foraminiferal species, it was concluded that the faunal distribution and assemblage would be best represented in terms of the genera, or in some instances, characteristic family level. The most common

occurring genera, in both formations, are represented by a single species. If the genus has more than one species, these species always occur in close association. Also, some genera can be grouped into a single Family. By using such categorized taxa the following figures (Figures 3-12) of distribution were constructed for each sample section.

### Trend of Occurrence

Most of the major taxa, which were subjected to the Regression Analysis of their variability with respect to depth, showed a significant variation in the tested sections although such variability is not present in all localities. Inconsistence in the variability may be due to lack of uniformity in the thickness of the examined outcrops, and cores, and to possibility in the faunal provincialism.

As a result of the Regression Analysis, some of the taxa which show a considerable depth dependence were presented with predicted trend in the following figures (Figures 13-22). This would enable one to predict distributional trend in the interval of a section where the actual samples are lacking or beyond the limit of the given lithic unit available for observation and help evaluate the interrelation between the taxa in view of their relative frequencies.

The regression figures are presented by the sample locality. Outcrops which yielded less than three paleontologic samples were omitted because of the irrelevance of the statistical treatment on such sections.



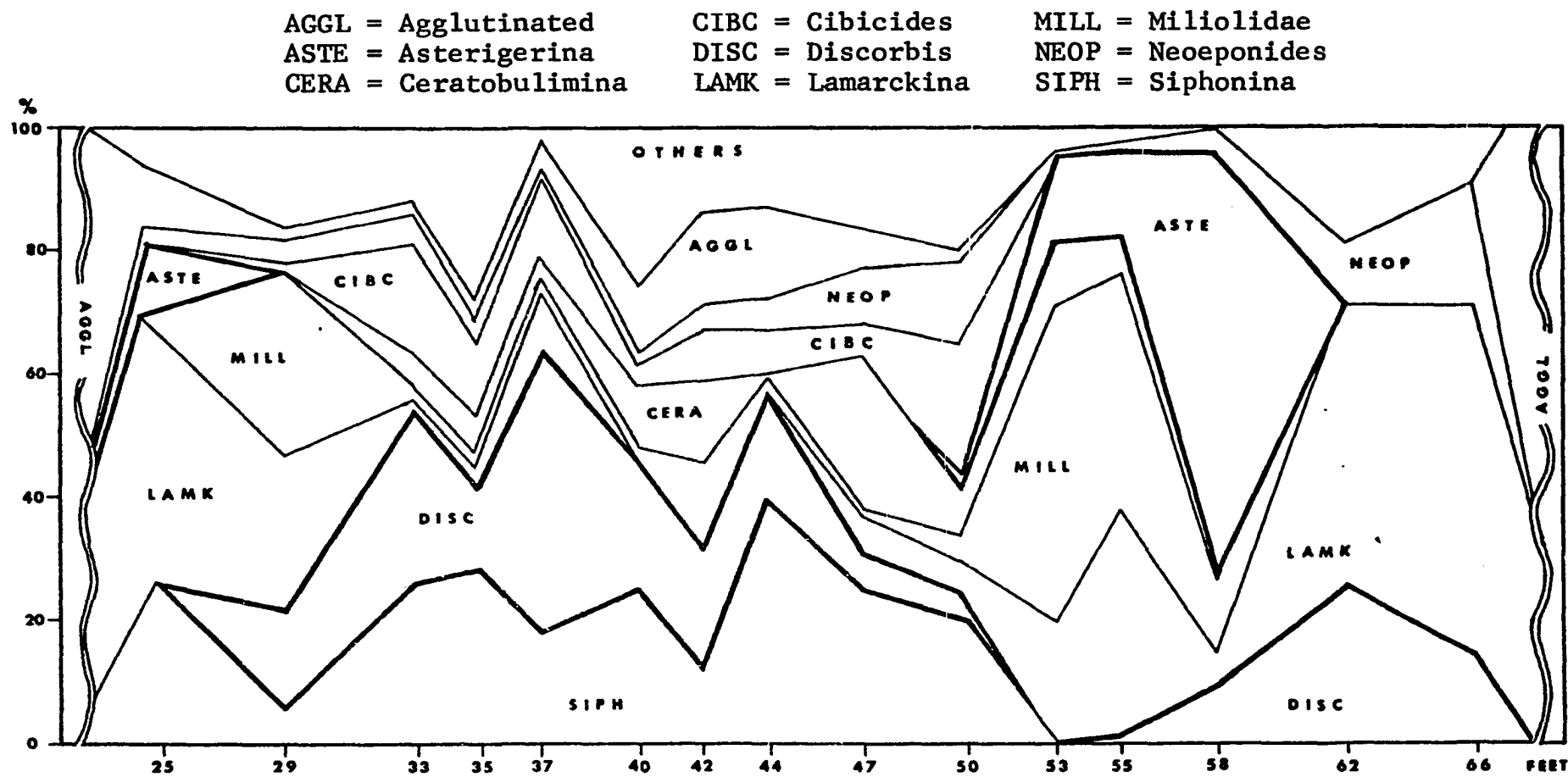


Fig. 3. Distribution of Selected Foraminiferal Taxa (1) Weches

ALAB = Alabamina	CIBC = Cibicides	ASTE = Asterigerina
LAMK = Lamarckina	DISC = Discorbis	SIPH = Siphonina
CERA = Ceratobulimina	NEOP = Neoeponides	

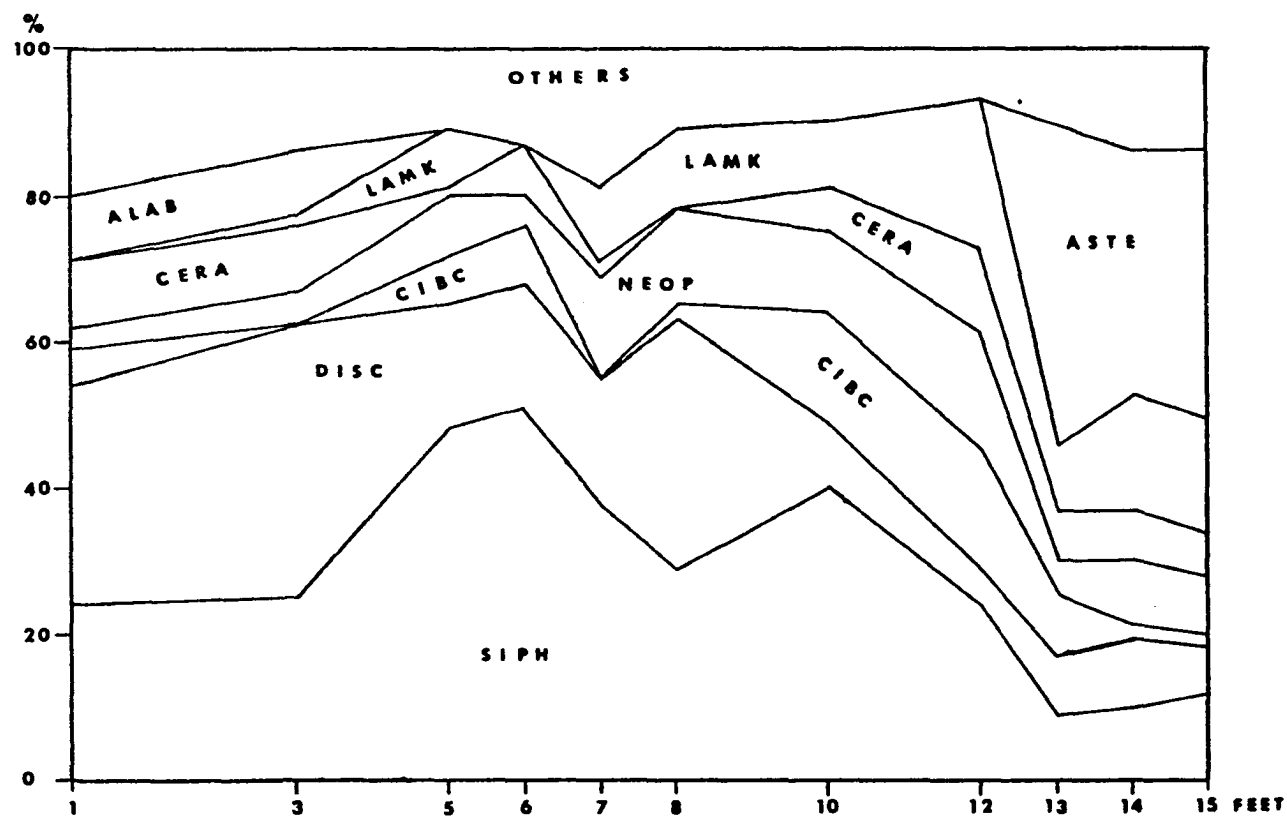


Fig. 4. Distribution of Selected Foraminiferal Taxa (2) Palestine

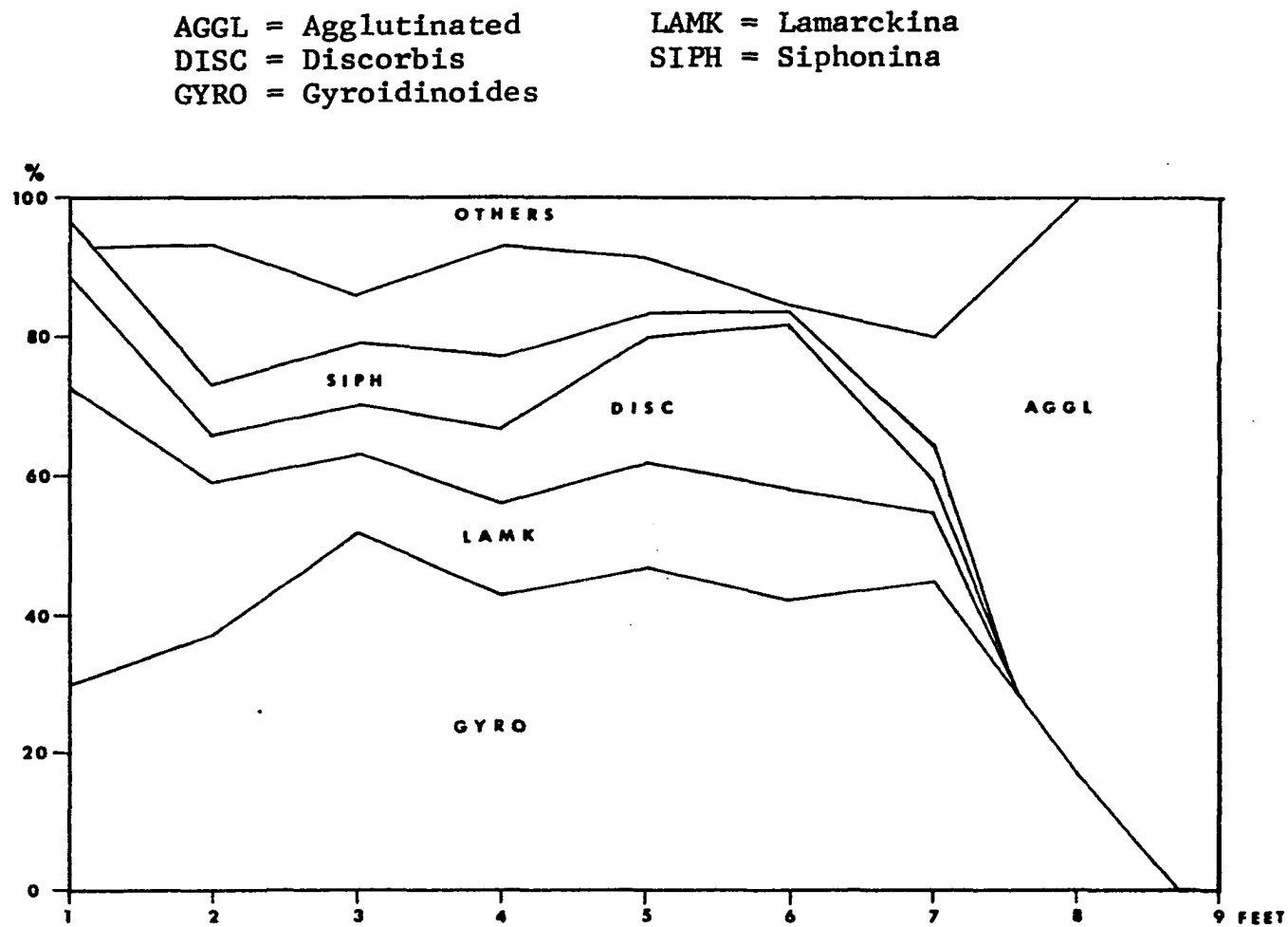


Fig. 5. Distribution of Selected Foraminiferal Taxa (3) Nacogdoches

ALAB = Alabamina	DISC = Discorbis	NEOP = Neoeponides
CERA = Ceratobulimina	LAMK = Lamarckina	SIPH = Siphonina
CIBC = Cibicides	MILL = Miliolidae	

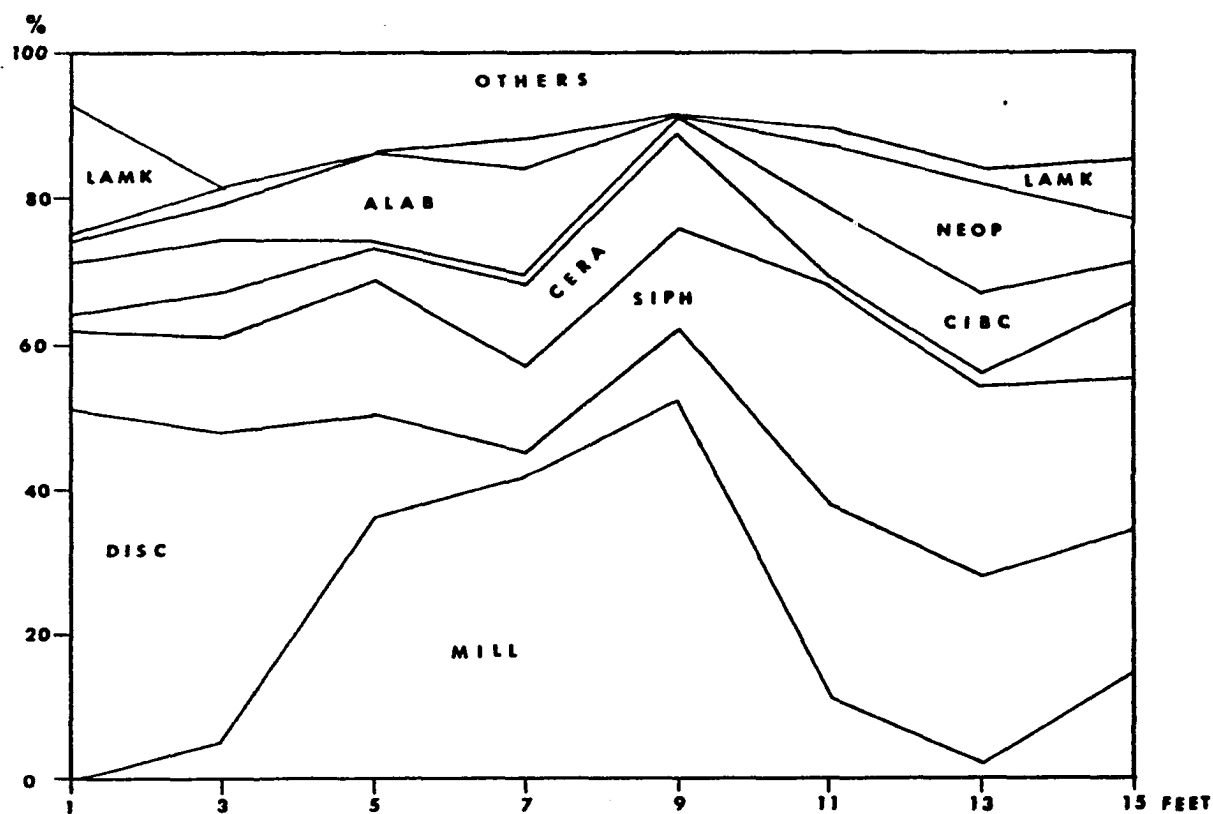


Fig. 6. Distribution of Selected Foraminiferal Taxa (5) Chireno II

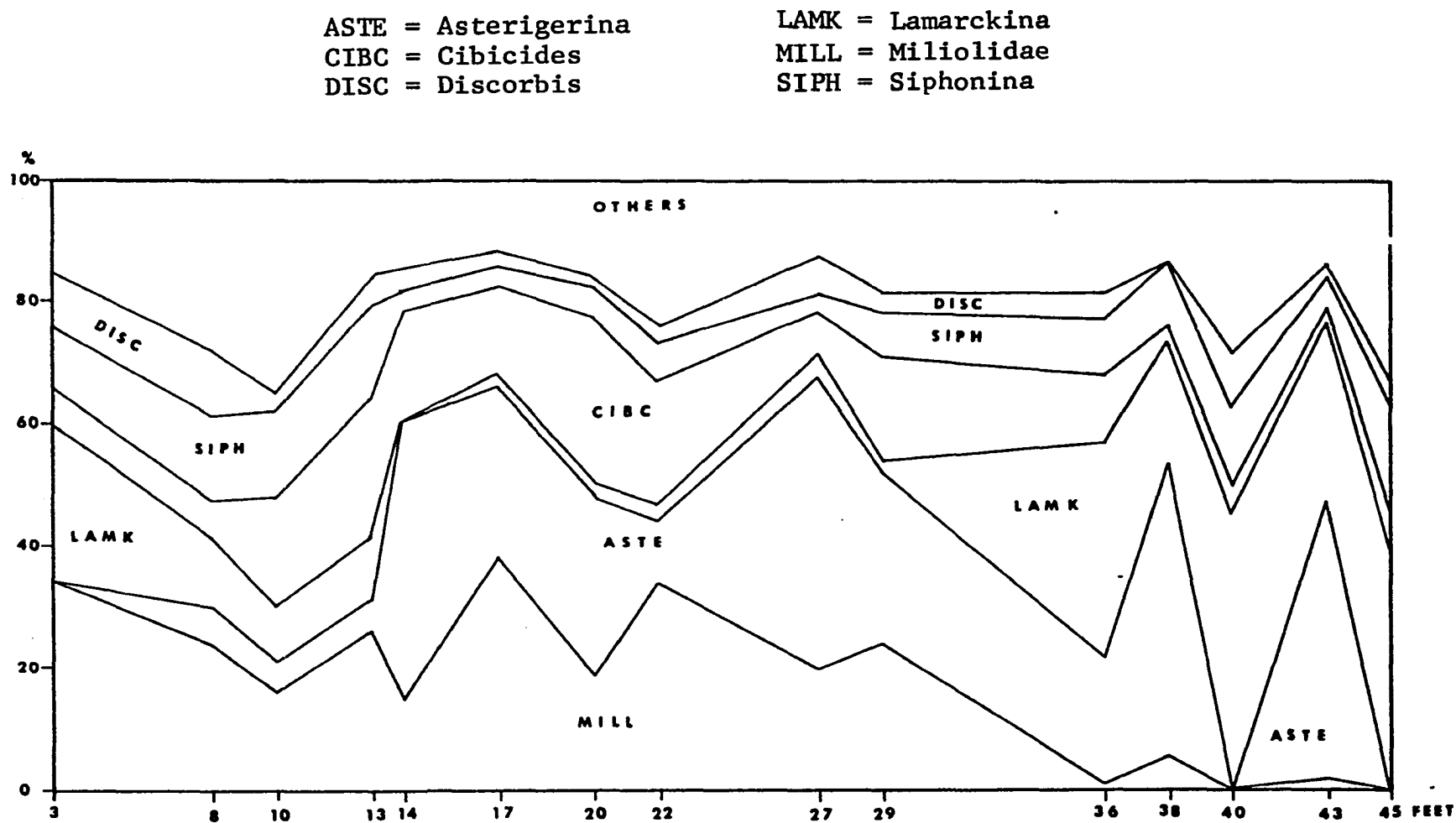
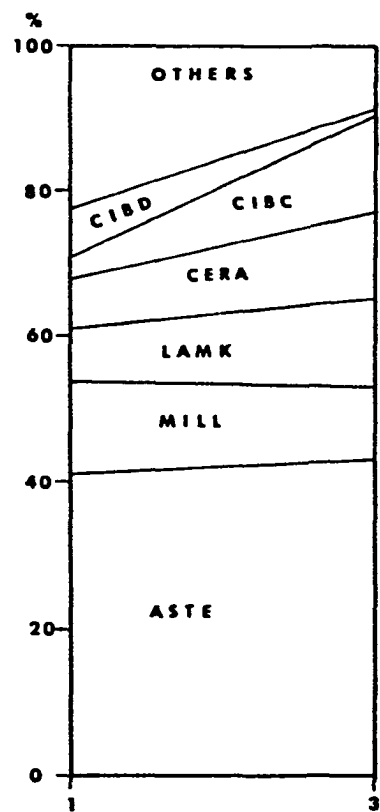
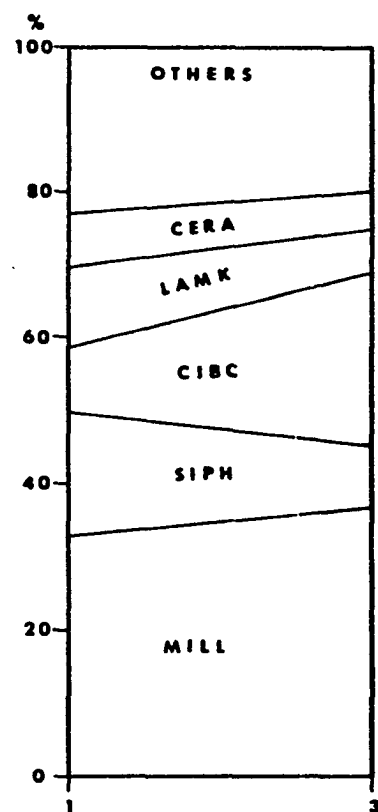


Fig. 7. Distribution of Selected Foraminiferal Taxa

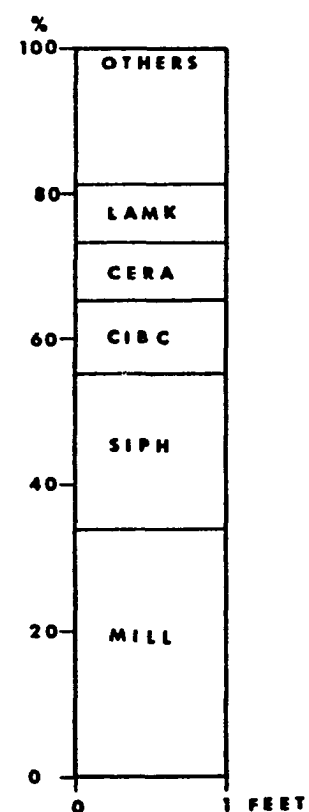
ASTE = Asterigerina      CIBC = Cibicidina      SIPH = Siphonina  
CERA = Ceratobulimina      LAMK = Lamarckina  
CIBC = Cibicides      MILL = Miliolidae



(4) Bayou Carrizo



(7) Bayou Attoyac



(8) San Augustine

Fig. 8. Distribution of Selected Foraminiferal Taxa

ALAB = Alabamina      CIBD = Cibicidina      SIPH = Siphonina  
 ANOM = Anomalinoides      GYRO = Gyroidinoides  
 CIBC = Cibicides      LAMK = Lamarckina

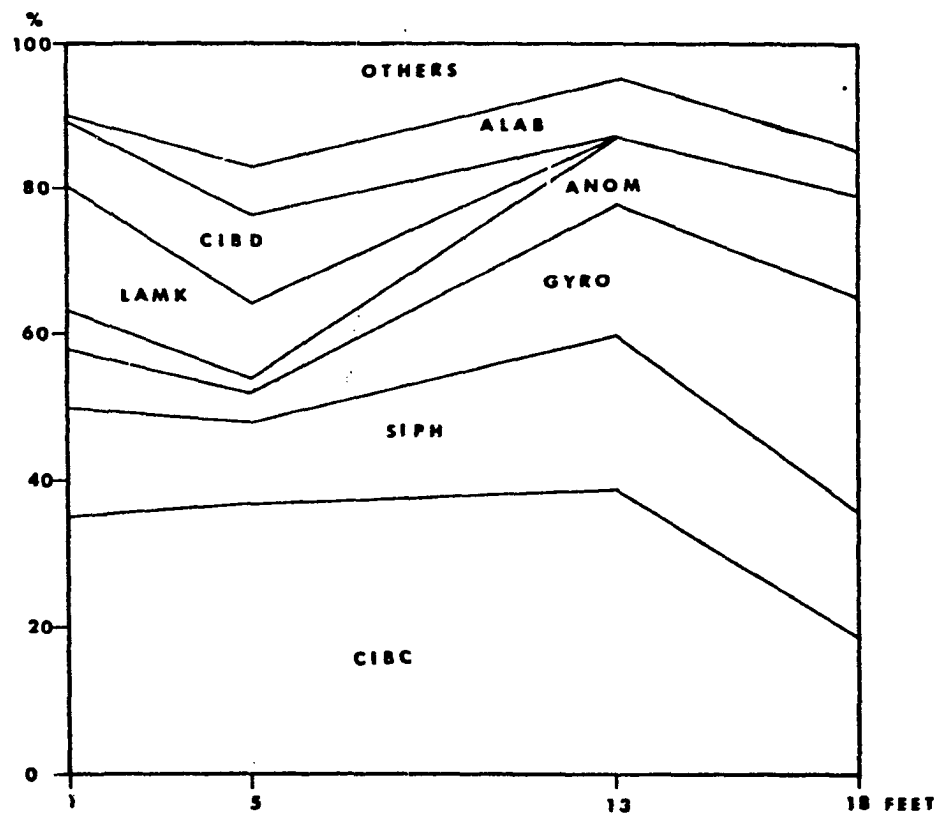


Fig. 9. Distribution of Selected Foraminiferal Taxa (9) Bayou Negreet

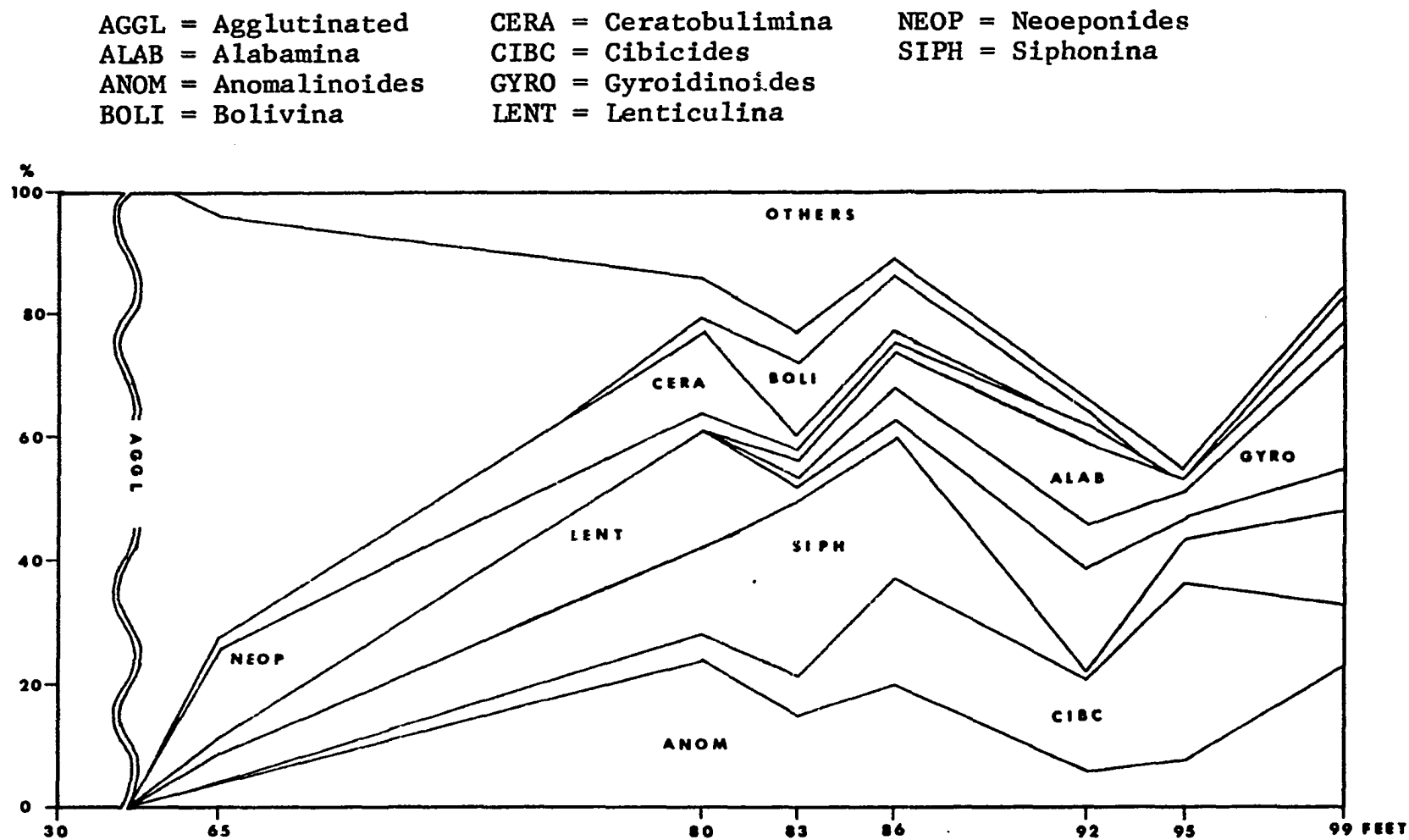


Fig. 10. Distribution of Selected Foraminiferal Taxa (10) Provencal



ASTE = Asterigerina      BULI = Bulimina      SIPH = Siphonina  
 ALAB = Alabamina      CIBC = Cibicides      UVIG = Uvigerina  
 ANOM = Anomalinoidea      GYRO = Gyroidinoides  
 BOLI = Bolivina      LENT = Lenticulina

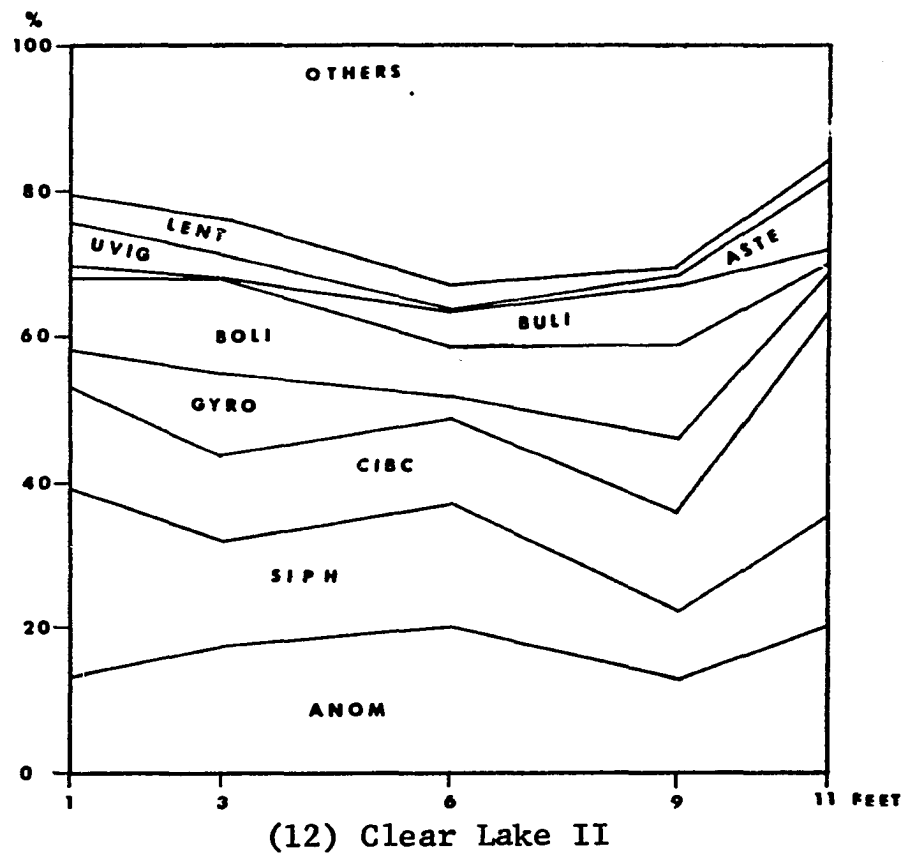
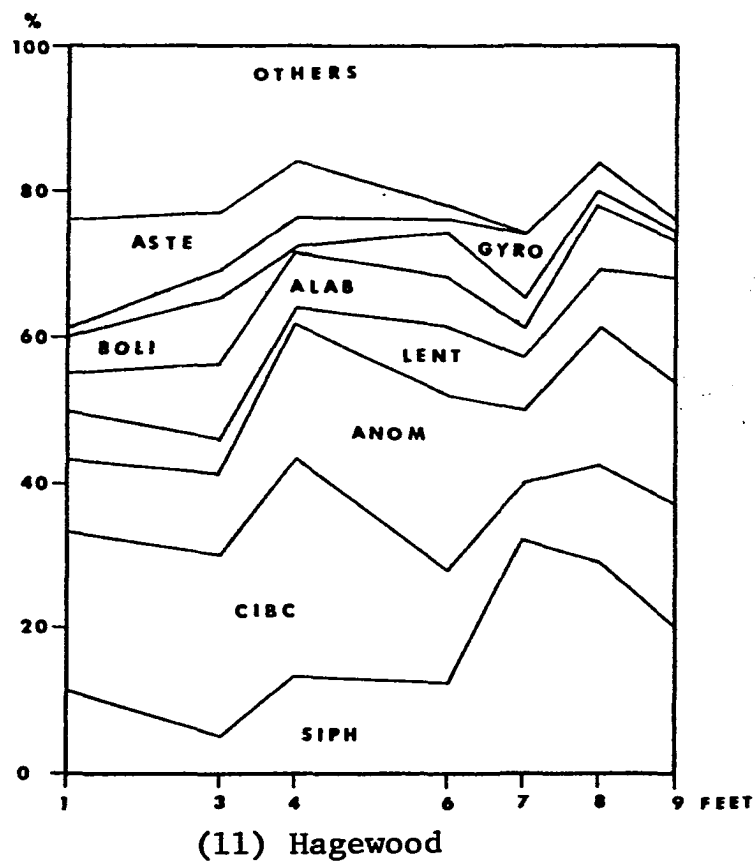


Fig. 11. Distribution of Selected Foraminiferal Taxa

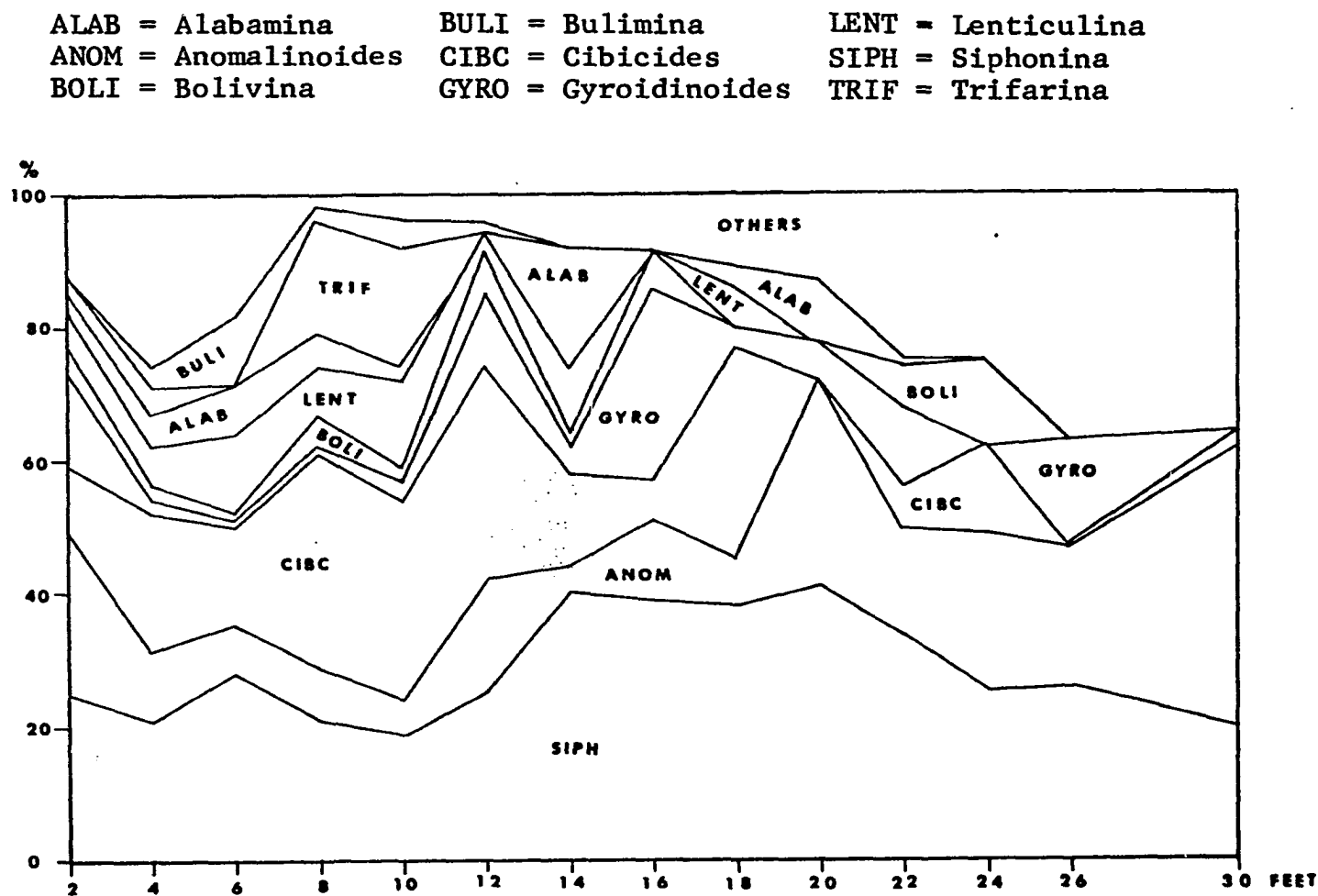


Fig. 12. Distribution of Selected Foraminiferal Taxa (13) Clear Lake

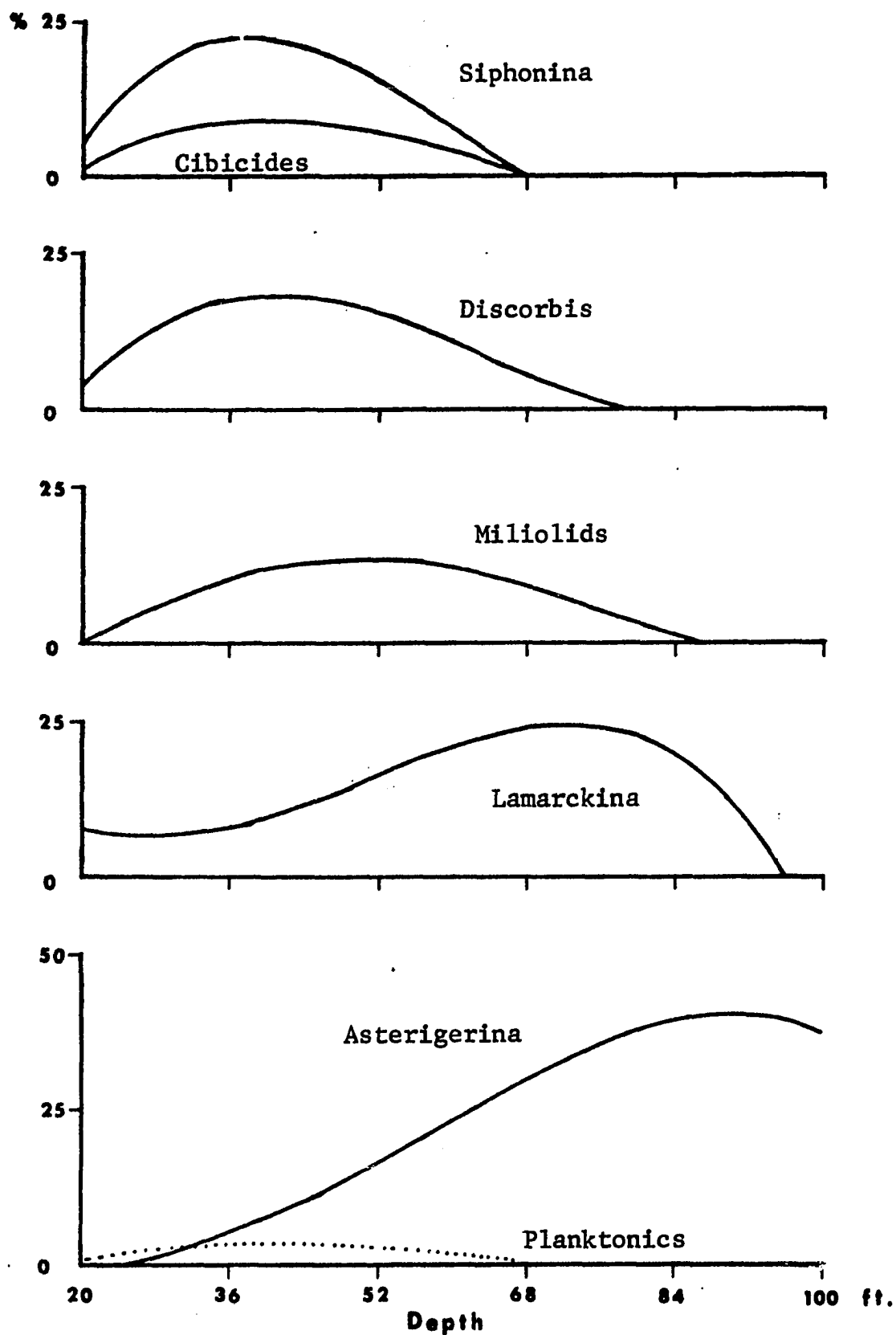


Fig. 13. Predicted Trend of Occurrence (1) Weches

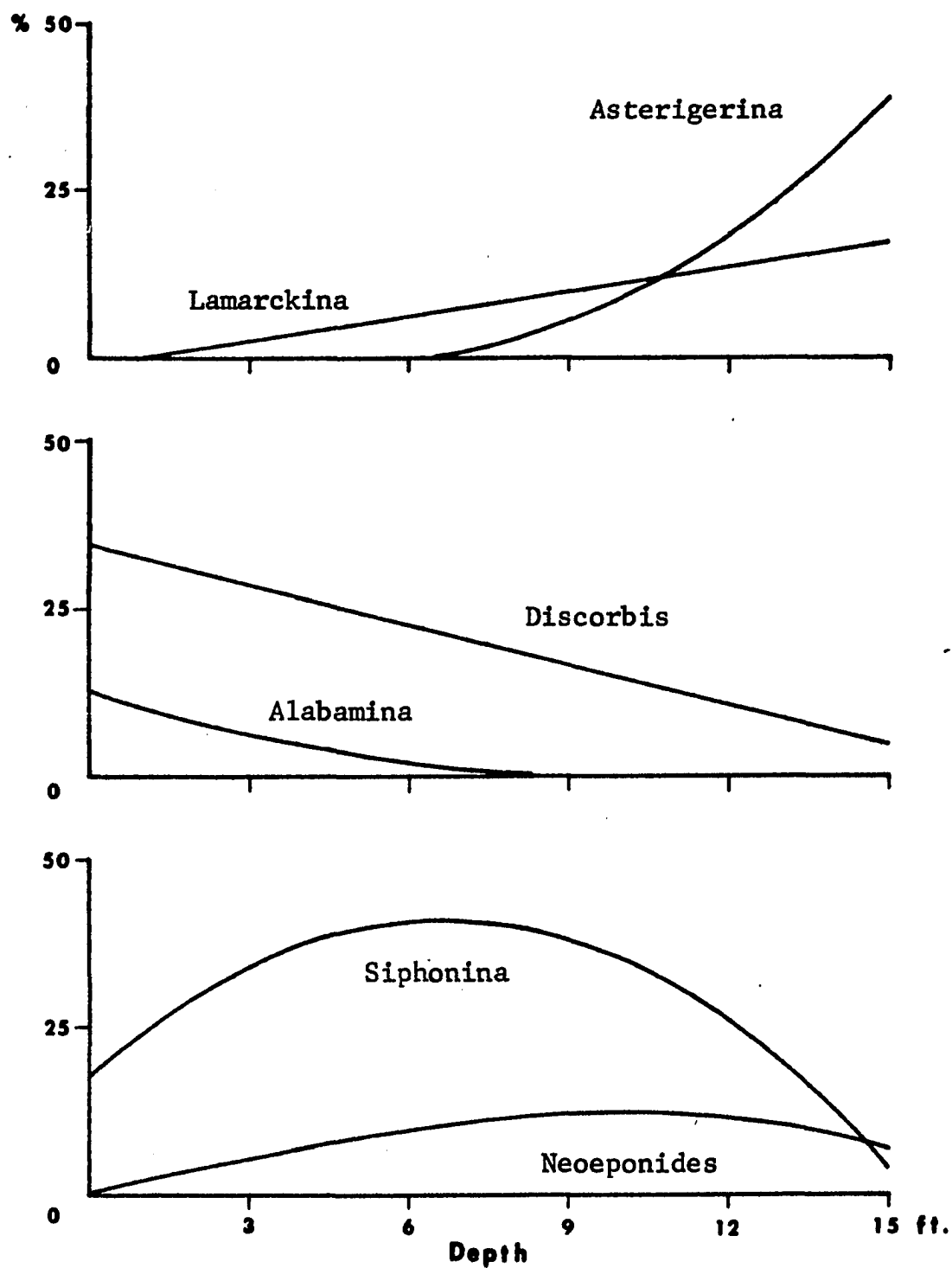


Fig. 14. Predicted Trend of Occurrence (2) Palestine

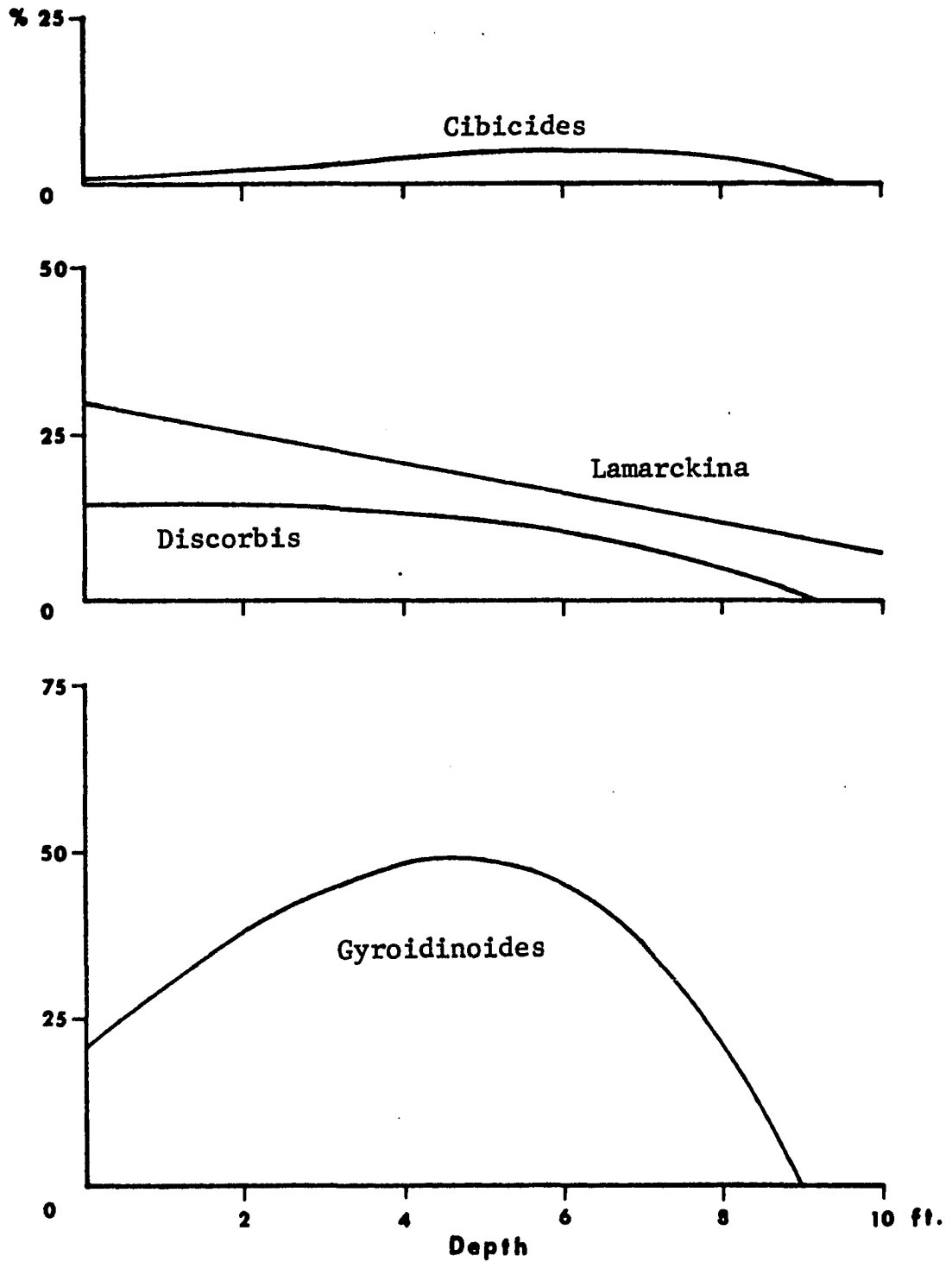


Fig. 15. Predicted Trend of Occurrence (3) Nacogdoches

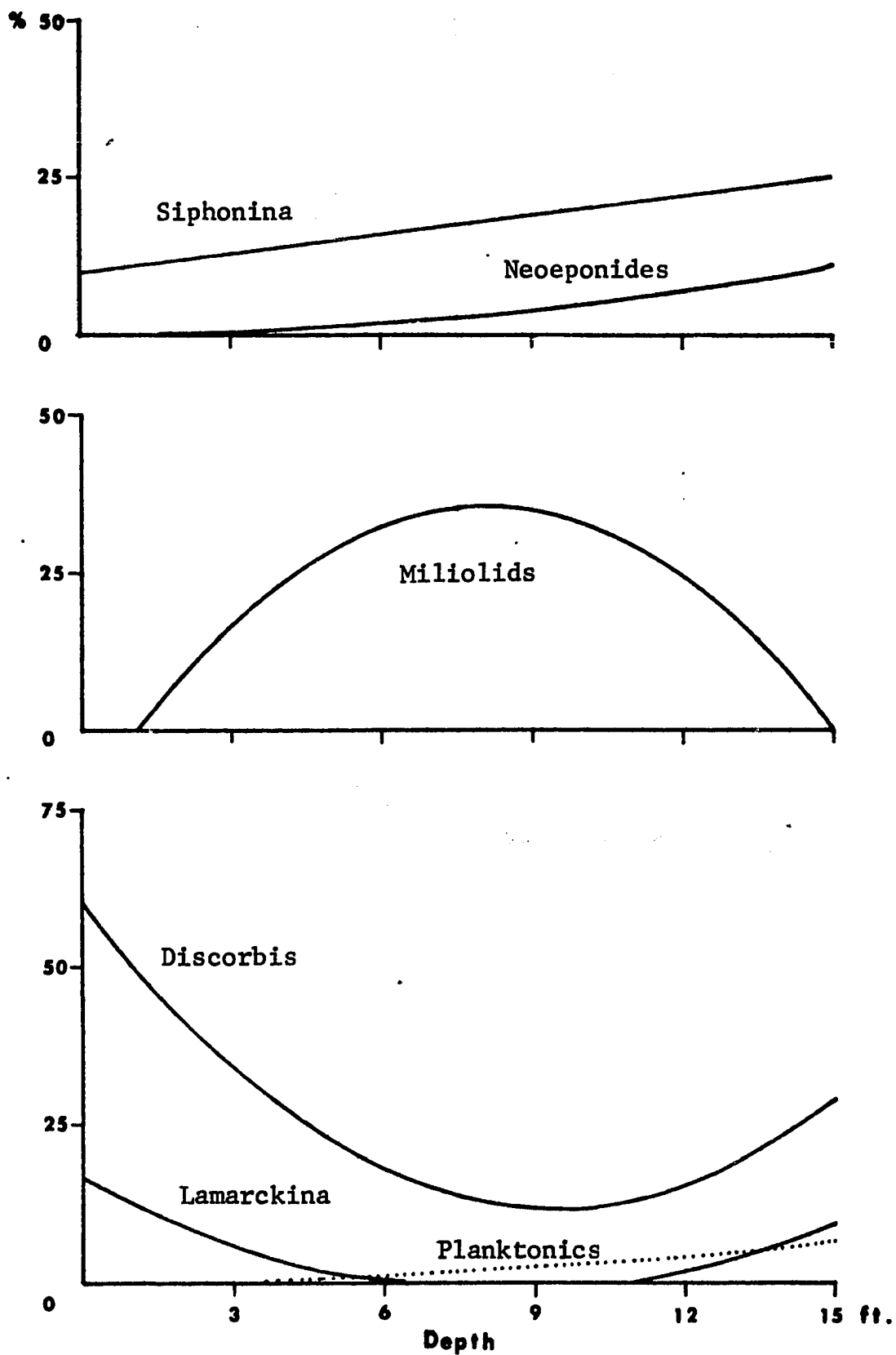


Fig. 16. Predicted Trend of Occurrence (5) Chireno II

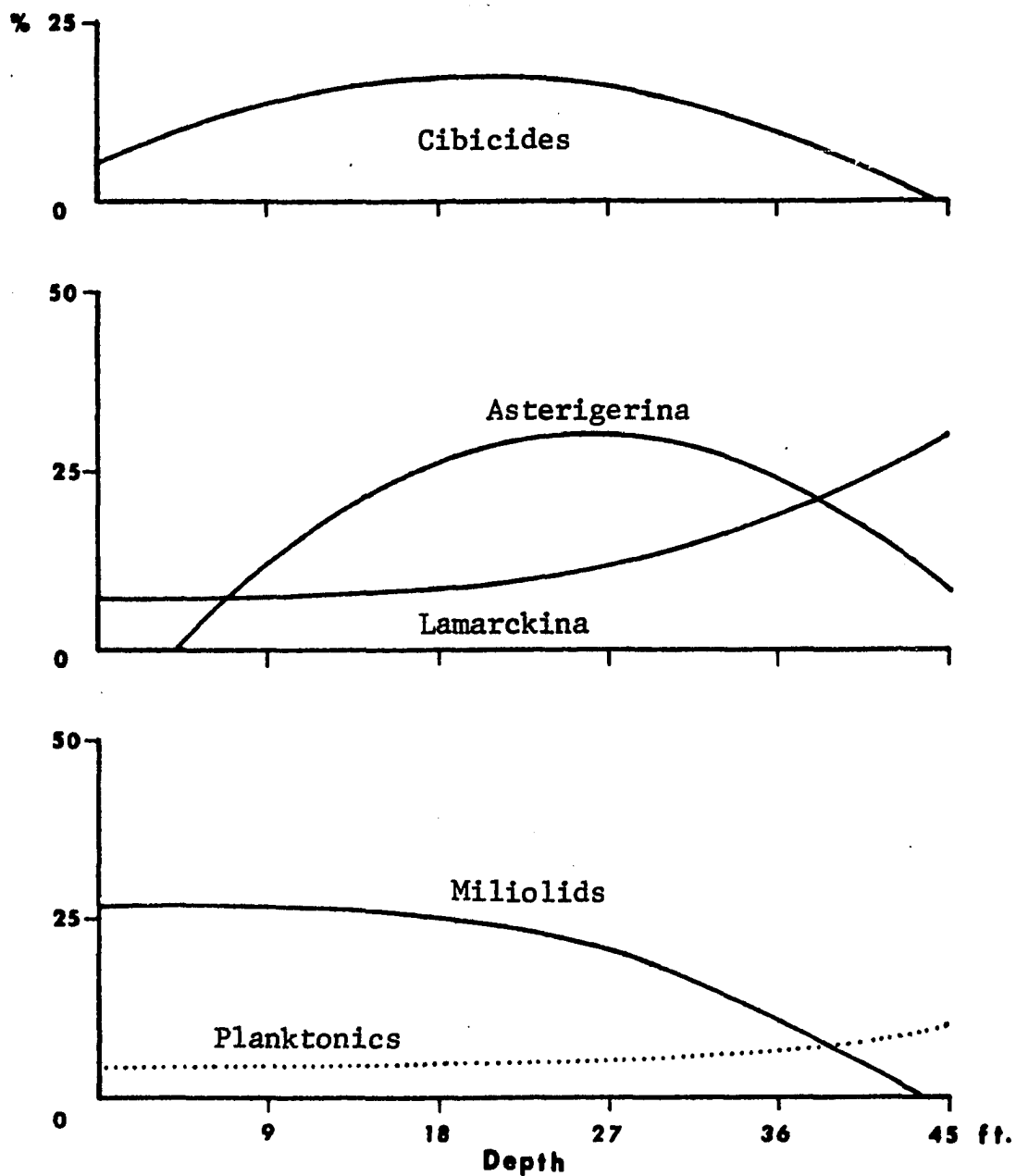


Fig. 17. Predicted Trend of Occurrence (6) Chireno

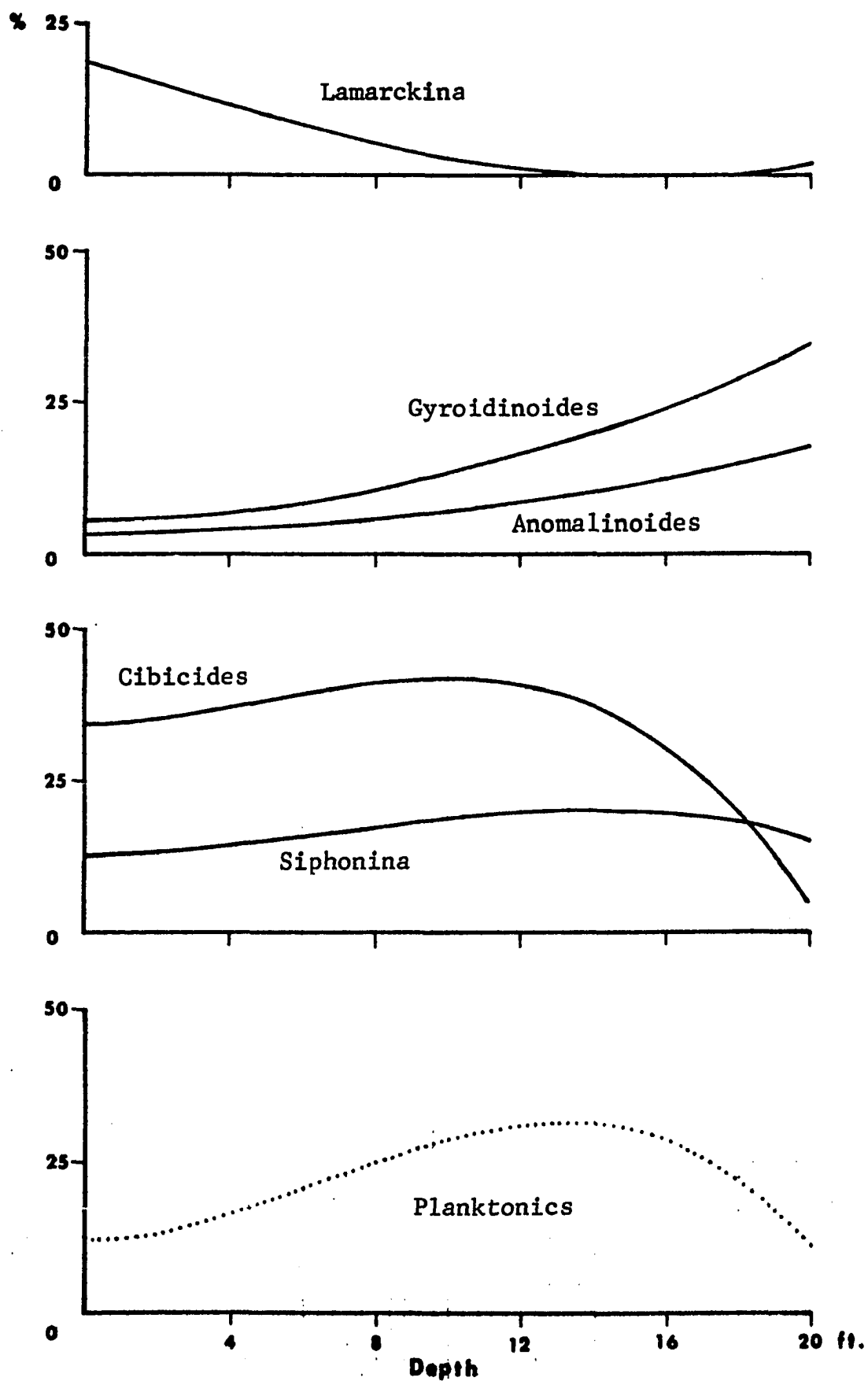


Fig. 18. Predicted Trend of Occurrence (9) Bayou Negreet



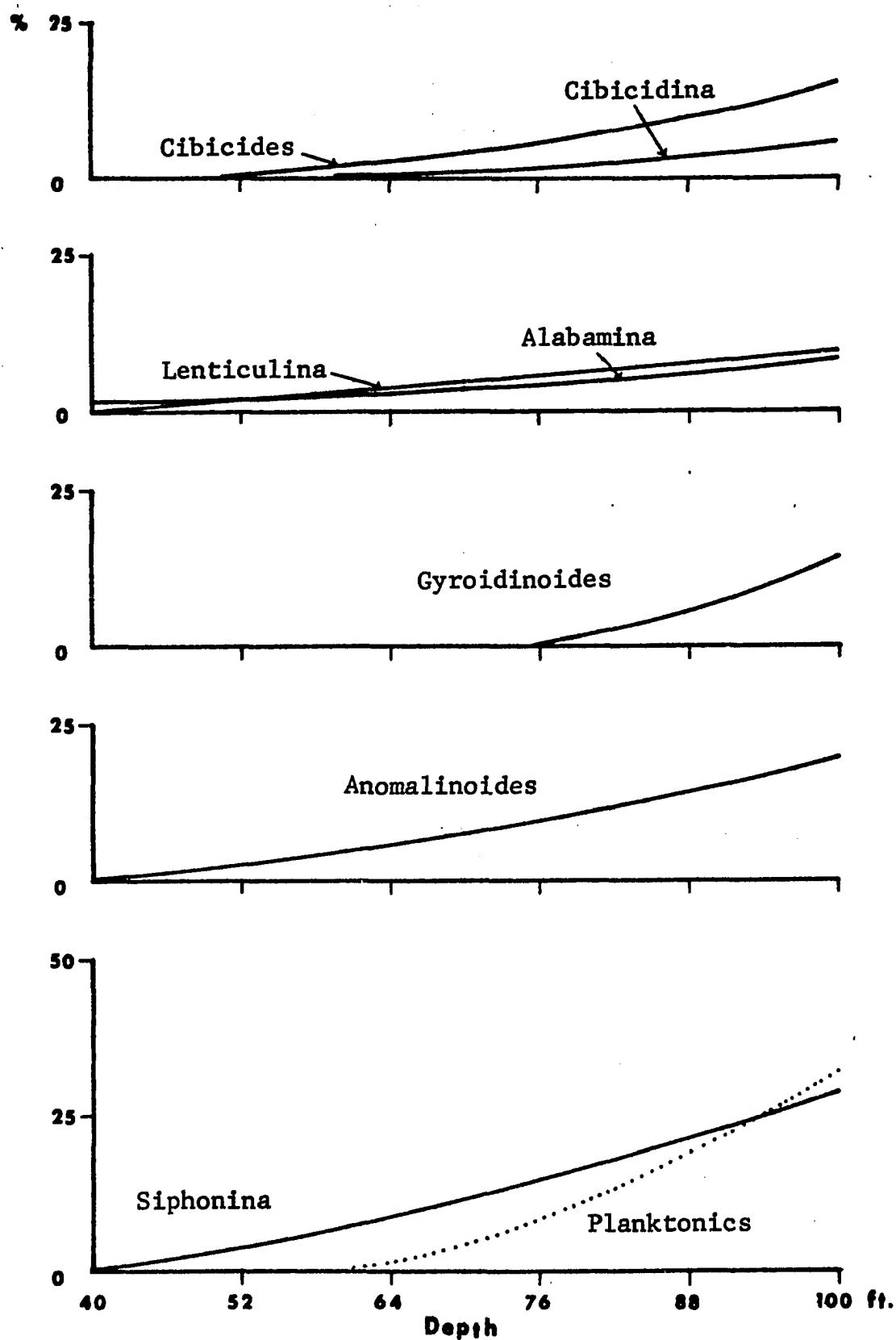


Fig. 19. Predicted Trend of Occurrence (10) Provencal

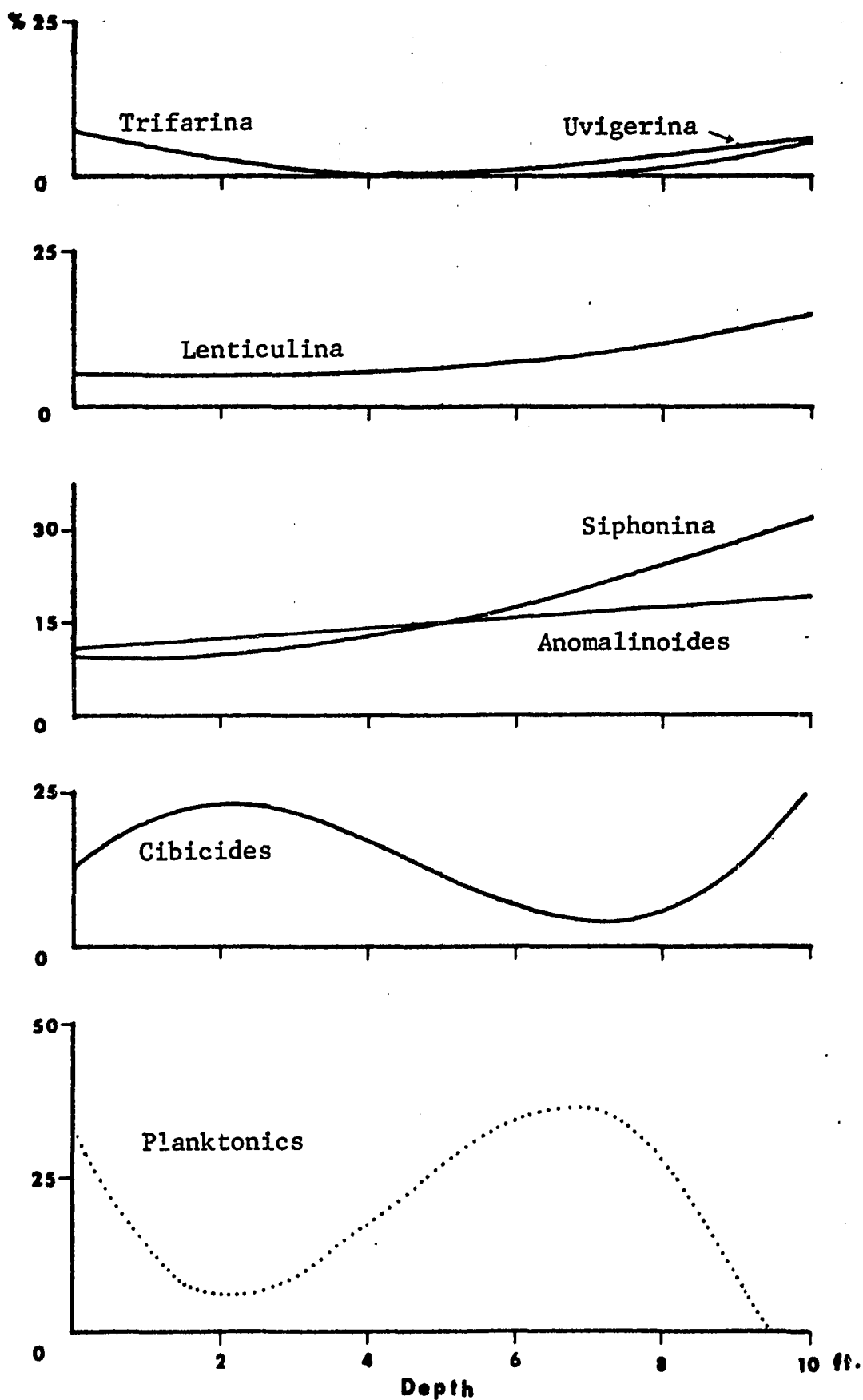


Fig. 20. Predicted Trend of Occurrence (11) Hagewood

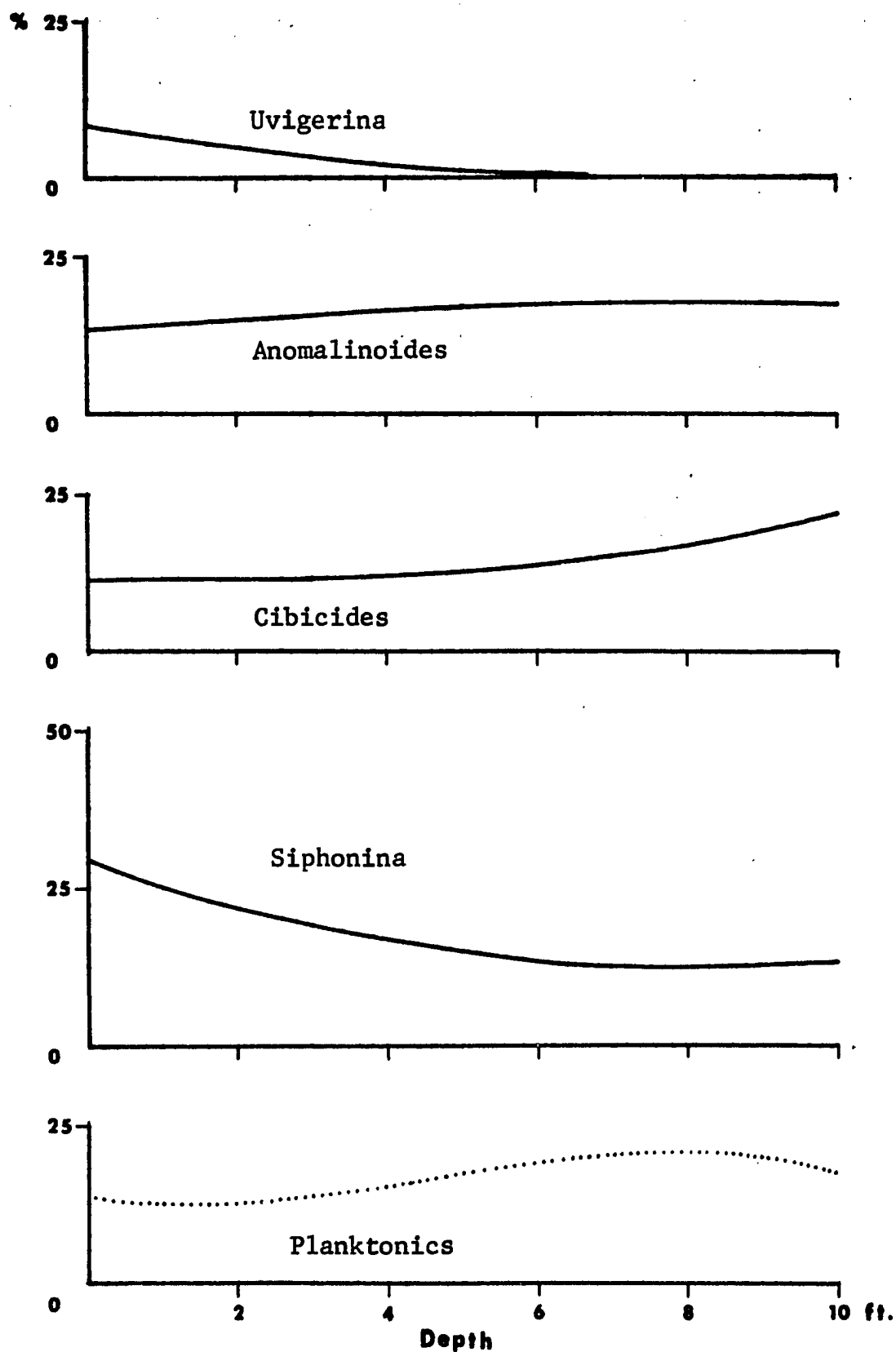


Fig. 21. Predicted Trend of Occurrence (12) Clear Lake II

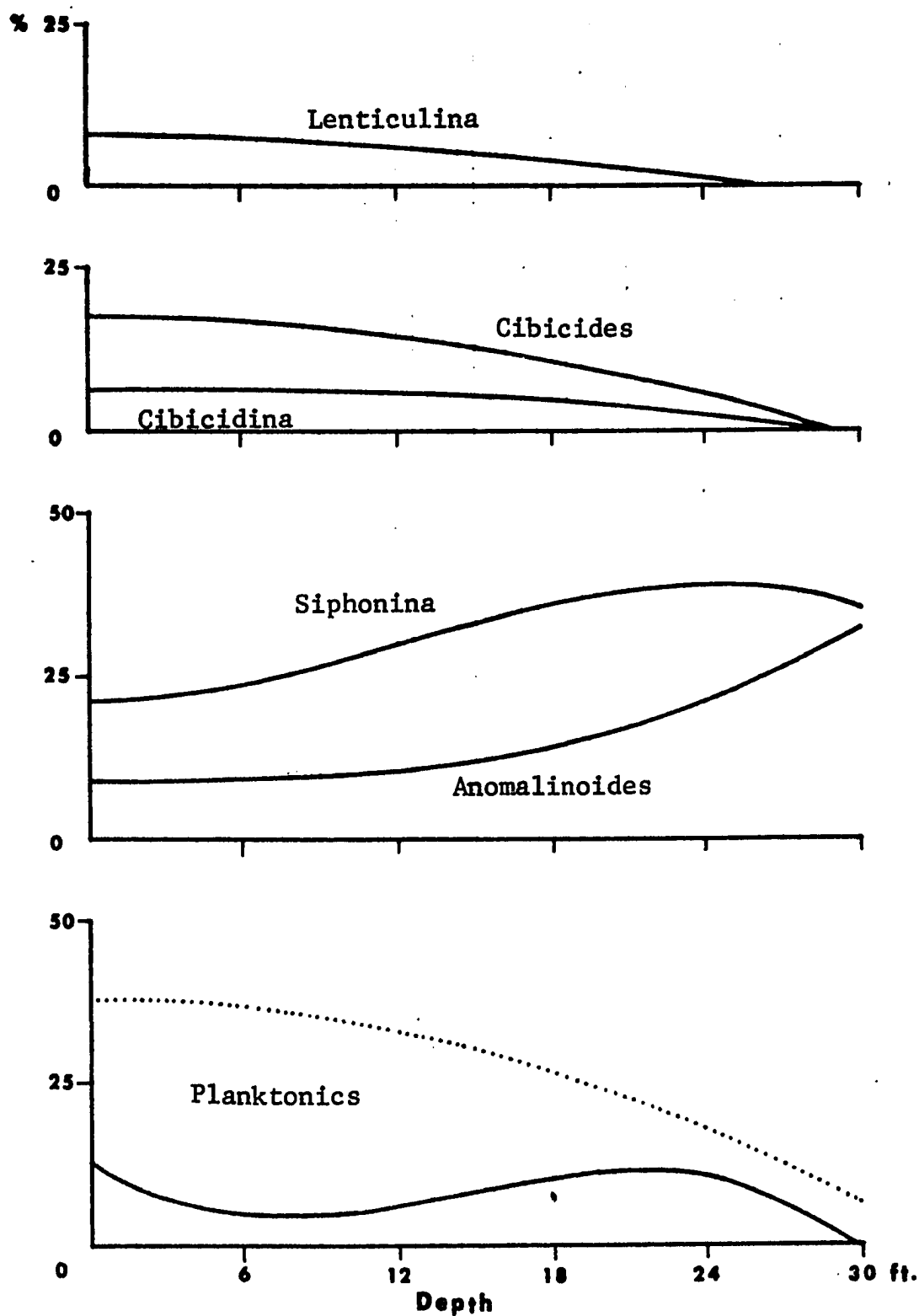


Fig. 22. Predicted Trend of Occurrence (13) Clear Lake

On the basis of actually observed data and predicted trends of Regression Analysis, the following trend of major foraminiferal taxa were recognized.

#### Agglutinated fauna

Agglutinated specimen consisted mainly of species from the families Lituolidae, Textulariidae, Trochamminidae, Ammodiscidae and Ataxophragmiidae. Almost all of the agglutinated species belong to the Lituolidae and Trochamminidae. Species of Family Ataxophragmiidae and Ammodiscidae are rare.

The above agglutinated fauna occurs mostly in the brown clay of transitional sections in both formations. In an early transgressive section they are quickly replaced by the normal assemblages. At the end of the marine transgressive environment a reversion of assemblages occur. The Family Textulariidae, on the other hand, has no definite trend within the two formations. It occurs sporadically throughout the localities but never attains a dominant position.

#### Calcareous fauna

##### Miliolidae:

In the Weches Formation, the miliolid population consists of a few species of Quinqueloculina which occur very abundant in most samples, and which appear to have wide lateral distribution at the depth range of the Weches environment. Species of Triloculina are almost exclusively Weches; however, they are never as abundant as the species

of Quinqueloculina.

In the Cane River Formation, the miliolids are insignificant to totally absent species of Quinqueloculina were recovered from the cores in central Louisiana; however, there was a complete absence of miliolids in western Louisiana. The frequency of occurrence was so low in central Louisiana that no significant trend could be established for the distribution of the species in the family.

Family Anomalinidae:

Species belonging to the anomalinoides are fairly abundant in the Cane River Formation associated with "Cibicides" and Siphonina. They gradually increase in number in the glauconitic section in which they parallel the increased concentration of planktonic species. The remaining genus, Melonis, occurs frequently in all localities regardless of locality and formation. Its frequency trend is most closely related to that of the anomalinoides species; however, Melonis alone does not show any significant variation.

Asterigerina and Lamarckina:

These two genera are very abundant in the lower unit of the Weches Formation. Their frequencies gradually decrease toward the upper part of the section where they are replaced by other taxa which dominate the assemblages. In the Cane River Formation, however, they occur as common species in a few isolated sections, more or less concentrated in the upper part of the section, although they never reach the degree of frequency attained in the Weches Formation.

Alabamina:

In either formation, Alabamina never occurs as a major species. It is commonly distributed throughout both formations, thus intimating that Alabamina has no stratigraphic significance.

Bolivina, Brizalina, Bulimina, Siphouvigerina, Trifarina,  
Uvigerina:

These are characteristic Cane River genera. Even in the Cane River sections, however, their frequencies are not persistent enough to show any major trend. Their combined number indicates that they are generally more abundant in that part of the formation which has a high ratio of planktonic species and high occurrence of Anomalinoidea and "Cibicides".

Ceratobulimina and Neoeponides:

These genera occur rather consistently in all Weches sections but less frequently in the Cane River. There seems to be no depth dependent variation in this group. Both genera occur abundantly; however, they never dominate either the Weches or Cane River assemblages.

"Cibicides" and Cibicidina:

"Cibicides" and Cibicidina occur more or less "hand-in-hand" in all assemblages, with Cibicidina being the minor accessory. "Cibicides" is the major species in all the Cane River assemblages studied; however, it also occurs abundantly in the Weches Formation with less frequency. The general trend of the two genera parallels that of Siphonina,

Anomalinoidea, and planktonic species in that they increase toward the middle of both the Cane River and Weches sections, and decrease toward the upper portion of these sections.

In the Weches sections, however, wherever there is a high percentage of Asterigerina, Lamarckina, and miliolids in the assemblage, "Cibicides" is conspicuously reduced. Cibicidina, a minor genus in all assemblages, seems to occur as an accessory in an assemblage where "Cibicides" is an important taxon.

"Discorbis":

This genus is one of the most distinctive taxa in separating the Weches Formation from the Cane River Formation. There are no "Discorbis" species reported from the Cane River Formation. In the Weches sequence, however, species of "Discorbis" occurs very abundantly throughout the sections; however, it does not seem to vary very much with depth, at least in the environment of the Weches sediments.

Lenticulina:

There is more diversity and greater frequency of this genus in the Cane River assemblages than any other genus; however, its relative frequency in the faunal assemblage is rather low compared with other major taxa. There is no particular trend for this genus. Lenticulina remains as a minor genus in the Weches formation with less diversity and frequency.

Siphonina:

Siphonina is the most abundant genus in both formations.



It occurs very persistently, as a major genus in the Cane River Formation, with Anomalinoides and "Cibicides". In the Weches Formation, however, its frequency is often overshadowed by the presence of species of other genera which predominate the assemblage. For example, whenever there is a high frequency of Lamarckina, Asterigerina, or Miliolidae, the frequency of Siphonina is substantially decreased.

In the Weches section, Siphonina and "Cibicides" show a somewhat similar trend.

#### Family Nodosariidae:

Except for the genus Lenticulina, all species of the Nodosariidae are rare in both formations. Species of Dentalina, Dentalinoides, Lagena, Marginulina, Nodosaria, Orthomorphina, Pseudonodosaria, Saracenaria, Vaginulina and Vaginulinopsis occur more frequently in the Cane River Formation.

#### Family Polymorphinidae:

Species of the genus Globulina, Guttulina and Sigmomorphina occur rather abundantly, often over 5%, throughout the Weches Formation; however, all are extremely rare in the Cane River Formation.

#### Family Discocyclinidae:

Discocyclina advena is the unique species of all Foraminiferas in the two formations. It occurs only in the upper Cane River sections, usually associated with Cubitostrea lisbonensis. Its relative frequency can not be measured in a regular quantitative sample because of the extraordinary size of the test. However, they are so

concentrated in a relatively narrow zone that it serves as an unmistakable marker fossil of the Upper Cane River.

Family Cassidulinidae:

In a few isolated samples of the Cane River Formation the genus Globocassidulina occurs very abundantly (up to 13%). However, it was observed only twice in the Weches Formation (Weches and Attoyac localities). There is no significant trend of occurrence in relation to other foraminiferal taxa in the assemblage.

Miscellaneous families:

All other species of various families are so rare in their occurrence that their trend of distribution can not be assessed properly.

Stenzel (verbal communication, 1974) suggested that the genus Ferayina may be an important index fossil for the Weches Formation. A single species of this genus (Chapmanina of Feray, 1948; Ferayina of Frizzell, 1949), was reported to occur only in two closely located areas in Bastrop County, Texas, which are southwest of the area covered in the present study. It seems to be locally confined in the Viesca member of the Weches Formation and can not be considered as a significant species in this study either biostratigraphically or paleoecologically.

Distributional Trend by Different Wall Structures:

It is apparent that within the samples studied, the bathymetry of test material and wall structure are rather inconclusive except for the agglutinated test. The majority

of the agglutinated species are concentrated in the transitional environment, as previously noted. Their frequency decreases quickly as the water depth increases.

Species with a porcelaneous wall also have a greater concentration in sediment considered to have been deposited in a very shallow open marine environment. Although genera with porcelaneous tests appear to prefer shallow water both in Holocene and Eocene time, it can not be determined for certain that the trend of the miliolid gener represents the environmental preference of the porcelaneous genera as a whole.

In the Claiborne samples, the main trend of the perforate calcareous faunas with granular and radial microstructure depends upon the frequency of a dominant species of a particular wall structure in the assemblage rather than on a taxonomic basis. Neither does the diversity of species show any generalization. This may be due to the fact that the depth variation in the studied environment was not great enough for the Foraminiferal microstructures to show any depth trend or that there is no organic relationship between the depth of environment and the above two types of wall structure. Further studies on samples of greater depth variation may result in more satisfactory conclusion; however, within the depth range of Claiborne samples examined, there is no definite frequency trend for either the faunas of granular microstructure or radial microstructure.

## Ostracoda

There are a number of studies on the Eocene Ostracoda (Alexander, 1934; Blake, 1950; Gooch, 1939; Howe and Chambers, 1935; Howe and Garrett, 1934; Martin, 1939; Murray, 1938; Stadnichenko, 1937; Stephenson, 1942, 1947; Sutton and Williams, 1939) of which those of Stephenson (1946) and Sutton and Williams (1939) were exclusively the taxonomic description of Ostracoda fauna from the locality at Smithville, Texas. In Louisiana, Howe and Chambers (1935) and Howe and Garrett (1934) described Jackson and Sabine Ostracoda respectively, but the Claiborne fauna has never been published. A few isolated monographs have been published in which several species of Cook Mountain and Cane River formations were illustrated (Gooch, 1939; Martin, 1939; Murray, 1938). Most of these works were taxonomic monographs with some biostratigraphic aspects of the species reported.

The paleoecology of the Ostracoda is still in its infancy and no reliable information is available at the moment to draw any independent conclusions on paleoecological implication of species distribution.

A list of these species and their source reference are given in the Appendix VI (B). No descriptions of the species are included.

In the present study 32 species from the Weches Formation and 29 species of Cane River Formation are

reported. This is the result of qualitative examination of Ostracoda fauna from the samples primarily prepared for the foraminiferal studies and no further efforts were made to quantify the information on the Ostracoda except frequency of occurrence in the samples.

Except for a few species, the majority of the Ostracods are present in both formations. Following is the list of Ostracoda from the two formations:

	<u>Weches</u>	<u>Cane River</u>
Acanthocythereis cf. washburni	*p	p
A. sp. A	p	
A. sp. B		p
Actinocythereis davidwhitei	p	p
A. (?) elmana		p
A. cf. hilgardi	p	p
A. sp.	p	p
Bairdia spp.	p	p
Brachycythere sp.		p
Buntonia howei	p	p
B. alabamensis	p	p
"Bythocypris" gibsonensis	p	p
Clithrocytheridea wechesensis	p	
C. sp.		p
Cocoaia smithvillensis	p	
"Cythereis" evergreenica	p	
"C." russelli		p
C. suttoni	p	
Cythereella sp.	p	p
Cytherelloidea smithvillensis	p	
Cytherura (?) sp.	p	
Digmocythere russelli	p	p
Haplocytheridea bastropensis	p	
H. lisbonensis	p	
H. ellisi	p	
H. habropapillosa	p	p
H. moodyi	p	
H. stuckeyi	p	p
Hemicytheridea (?) sp.	p	p
Hermanites (?) claibornensis	p	p
Loxoconcha chamfera		p
L. claibornensis	p	p
Ouachitaia gosportensis	p	
O. semireticulata	p	p
Opimocythere martini	p	
Paracypris franquesi		p

\*p = present

	<u>Weches</u>	<u>Cane River</u>
Pterygocythere bernardi		p
P. murrayi	p	p
Quadracythere winniana		p
Trachylebereis (?) linospinosa	p	p
T. orelliana	p	p
Xestoleberis dumblei		p

There are 19 species which occur in both formations. While the two formations possess almost an equal number of species, some are restricted to one or the other formation.

Following species are common to both formations.

Actinocythereis davidwhitei  
A. (?) sp.  
A. cf. hilgardi  
Cytherella sp.  
Digmocythere russelli  
Haplocytheridea stuckeyi  
Hermanites (?) claibornensis  
Trachyleberis orelliana

All these species are confined to a "normal" marine environment, and all are rather randomly distributed throughout the samples studied. Actinocythereis (?) sp. shows a somewhat locally concentrated distribution in the vicinity of Chireno, Texas, and Provencal, Louisiana. Cytherella sp. seems to occur more frequently associated with a rich mollusk fauna or in a zone very close to a heavy concentration of mollusks.

The following species are present only in the Weches Formation or occur very rarely also in the Cane River Formation:

Cocoaia smithvillensis  
"Cytheries" evergreenica  
Cytherelloidea smithvillensis  
Haplocytheridea bastropensis

H. ellisi  
H. habropapillosa  
H. lisbonensis  
H. moodyi  
Hemicytheridea  
Loxoconcha claibornensis

Haplocytheridea habropapillosa seems to possess a wider range of environmental tolerance. It commonly occurs in the marginal marine environment where the foraminiferal assemblages are dominated by agglutinated species, particularly species of Family Lituolidae. It also frequently occurs throughout a section which may range down to middle neritic depth. Other species are more or less limited to the glauconitic units representing deposition in open marine environment.

The following species occur only in the Cane River Formation or may occur also in the Weches samples with extremely rare frequencies. They do not show any particular pattern of distribution and occur randomly in glauconite rich sections throughout the localities sampled.

Acanthocythereis cf. washburni  
Brachychythere sp.  
Cythereis russelli  
Loxoconcha chamfera  
Quadracythere winniana

## Mollusca

The molluscan species examined were restricted to those of very small size which could be observed along with other microfossils present in a limited amount of sediment such as would be obtained from core samples.

In the recent studies of small molluscan fauna, their stratigraphic and environmental value has been recognized. The molluscan species of microscopic size were designated as "micromollusca" by some authors limiting the size of such a group to less than 6 mm in maximum diameter (Corgan, 1967). In the present study, however, size limitation was not imposed upon the mollusks. Correct or not, all the small specimens retained upon the 250 mesh screen were called micro-mollusks. The majority of the specimens studied, however, were actually less than 6 mm in maximum diameter.

There is a strong possibility that some of the Claiborne species of mollusca may have been regarded as juveniles of a larger species rather than the adult of a smaller species. Identification of the molluscan fauna, which follows, is tentative. It will serve as a guide to affinities apparent if any further examination of this group is attempted.

A list of "micromollusca" which occur in the Weches and the Cane River follows:



BIVALVIA	Weches	Cane River
<i>Alveinus minutus</i> Conrad	p	p
<i>Caestocorbula murchisoni</i> (Lea)	p	p
<i>Cuna parva</i> (Lea)	p	
" <i>Lucina</i> " <i>primoidea</i> Aldrich	p	p
<i>Limopsis radiata</i> Meyer		p
<i>Modiolus</i> (?) sp.	p	
<i>Notocorbula texana</i> (Gabb)	p	
<i>Nucula</i> ( <i>Nucula</i> ) <i>magnifica</i> Conrad	p	p
<i>Venericardia</i> cf. <i>tortidens</i> Harris	p	p
<i>Vokesula smithvillensis smithvillensis</i> (Harris)	p	p
GASTROPODA		
<i>Actaeonema sulcatum</i> (Lea)	p	p
<i>Athleta</i> cf. <i>lisbornensis</i> (Aldrich)	p	p
<i>Mitrella</i> (?) sp.	p	p
<i>Neverita</i> cf. <i>limula</i> (Conrad)	p	p
<i>Pyramidella</i> cf. <i>meyeri</i> (Cossmann)	p	p
<i>Ringicula</i> cf. <i>biplicata</i> (Lea)	p	p
<i>Terebra</i> cf. <i>jacksonensis</i> Cooke	p	p
<i>Terebra</i> (?) sp.	p	
<i>Tuba</i> sp.	p	
<i>Turritella arenicola danvillensis</i> Stenzel and Turner	p	p
<i>Turritella rivurbana</i> Cooke	p	p

Most of species are randomly distributed throughout the localities studied. The most abundant species are *Alveinus minutus*, *Venericardia* cf. *V. tortidens*, and *Pyramidella* cf. *P. meyeri*. These species are so ubiquitous that if their correct stratigraphic range could be determined they would serve as valuable index fossils whenever other micro-fauna is lacking. Except for those species mentioned above, micromollusca in general occur without any distinctive relationship to either lithology or stratigraphy.

When the overall content of molluscan fauna is examined, it seems that the Weches Formation contains more abundant fauna than the Cane River; however, this has not been

substantiated quantitatively.

Important species of Mollusca, other than micromollusca in a preceding list are Cubitostrea lisbonensis and Cubitostrea smithvillensis which have special stratigraphic value.

### Bryozoa

A total of 11 species of Bryozoa were observed from the two formations in the area studied. As in the case of Molluscal species, bryozoas show no distinctive characteristics in their distribution. All of bryozoan species are associated with faunal assemblages of the open marine environment and within the range of the Weches and Cane River environments, depth of water appears to have little affect on their distribution. Following are the species of Bryozoa from the two formations:

	<u>Weches</u>	<u>Cane River</u>
Adeonellopsis cyclops Canu and Bassler	*p	
Conescharrellina sp.	p	p
Conopeum lamellosum Canu and Bassler	p	
Ellisina claibornensis McGuirt		p
Holoporella granulosa Canu and Bassler	p	p
Nellia oculata Busk	p	
Otionella perforata Canu and Bassler	p	p
Schizorthosecos interstitia Lea	p	p
Schizorthosecos radiatum Canu and Bassler	p	
Trochopora bouci Lea	p	p
Trochopora truncata De gregorio	p	p

\*p = present

## Other Invertebrates

Anthozoa and Echinodermata occur in much less diversity and frequency than the other faunas. The Anthozoa species are represented by 3 species of corals. Only the fragments of Echinoderms were recovered from several samples of the Weches localities.

Three species of Corals are:

Turbinolia pharetra Lea  
Discotrochus sp.  
Platytrachus stokesi (Lea)

Turbinolia pharetra Lea is the most abundant species of the three occurring in almost all of the sections of the marine sequence of the Weches Formation examined. In the Cane River Formation, Turbinolia occurs only in a narrow zone of glauconite confined to two localities near the vicinity of Provencal. It was also noted that the zone of Turbinolia, in the Cane River, occurs immediately below the marginal marine environment of predominantly arenaceous foraminiferal assemblage.

Discotrochus sp. was observed only from one Weches locality at Nacogdoches, Texas. Throughout the entire length of the section it occurs securely attached to small gastropod shells.

Platytrachus sp. occurred only once in the Weches sample. It is not a common member of either formation. (The living species of this genus is known to be restricted in the depth range of 27 -130 m).

Echinoderm species occur sporadically in several samples, but their fragmental remains defy identification. Fragments of echinoderms, however, are more common in the Weches samples.

## FORAMINIFERAL ECOLOGY

### Nature of Studies and Their Paleoecologic Value

Most studies on the ecology of foraminifera are confined to relatively small areas, and are concerned with a specific environment. The results of these studies generally show that the pattern of faunal distribution is consistent within similar environments even though, geographically, the localities are widely separated. The usefulness of these ecological data to paleoecologic interpretation depends on the persistence of recent faunal characteristics through time. This is generally recognized, at least in a broad sense. In paleoecological study it is assumed that the bathymetry and geographic distribution (relative position in the marine environment) of the genera of a living fauna occupied the same ecologic niche in the past, although there are some anomalous instances contradicting such assumptions.

Very few species of Paleogene age persist into the Holocene; therefore, criteria based on species are either not usable or at best unreliable due to the restricted geologic ranges of species. It is reasoned that the extrapolation of ecologic criteria to the fossil community would be more reliable if it is confined to the generic level and in similar geographic regions. Also, in order for the ecologic data to be used as a guide to paleoecologic studies, it is necessary that the ecologic data be synthesized and averaged.

By doing so, some local anomalies of ecologic data are suppressed and which minimizes the probability of error in extrapolating ecologic criteria to ancient environments.

### Sources of Variation for Ecologic Distribution

The most important ecologic factors are salinity, depth of water, circulation of water mass, nutrients, water chemistry, turbidity, solar energy, and organic communities. Most probably, the combination of those interrelated factors play an important role in ecologic settings while one or more combinations of a few factors may be more effective in some areas.

At the present, only empirical findings are available for the relationships between faunal distribution and ecologic factors. Studies on the genetic nature of the organism in relation to environmental conditions are few and realized to be difficult at the present state of biologic knowledge on the subject. The tolerance range of survival and reproduction of Foraminifera is known to be relatively wide and only fundamental assumptions can be made. In the near-shore environment, especially in the transitional area where seasonal change of fresh water discharge has the greatest influence, salinity seems to be the governing factor on the kinds and distribution of foraminifers. Also, this zone lies within the higher energy environment where interactions between ecologic factors are most active. Salinity, however, shows the most variation which follows closely with anomalous

faunal distribution in an area. Temperature and depth are proportionally related. Among many ecologic workers, depth is often preferred to temperature because of the seasonal instability of temperature in the shallower environments of near-shore marine and the relatively insignificant variability of temperature beyond a certain depth. Temperature seems to be a controlling factor on the distribution of some planktonic species (Bandy, 1960a, 1960c; Beard, 1969; Berggren, 1968; Emiliani, 1954; Frerichs, 1971; Kane, 1953, 1956; Lowenstam and Epstein, 1954; Parker, 1960) but the pattern of distribution of benthonic faunas is more readily responsive to the depth of water because most benthonic faunas are known to have a rather wide range of temperature tolerance for survival and reproduction.

Other factors that vary with depth, which directly or indirectly influence faunal distribution, may also be summarized into a depth variable. Such factors as food availability, pH, substrate condition, Eh., and solar energy have not been studied sufficiently enough to make any general assumptions. A few isolated studies in these relations on some shallow water foraminifers have not resulted in definitive conclusions (Bradshaw, 1957, 1961; Loep, 1956; Murray, 1963; Myers, 1935a, 1935b, 1936; Phleger and Soutar, 1973). Therefore, for this paleoecologic evaluation of the Foraminifera in the Cane River and Weches Formation samples, bathymetry and salinity seem to be the only common denominator among the Foraminifera at the moment.

## Classification of Environments

Following is a most commonly accepted classification of environments in which distinctive living foraminiferal communities are found:

### I. Transitional Environment

This environment is subject to seasonal change and most of the time is under lower salinity. Delta, sound, bay, estuary, marsh, brackish lake and coastal lagoons are included in this zone. Although each subenvironment can be defined by its own faunal assemblages, mixing of fauna is not uncommon due to the contamination from adjacent areas. Boundaries within transitional environments are also gradational and subtle differences among those environments are almost impossible to detect by fossil assemblages alone in a sedimentary sequence. This zone can be divided into two broader environments.

1. Brackish Environments - delta, inner part of bay, marsh, estuary, brackish lake.
2. Protected Marine - sound, outer bay area, coastal lagoon.

### II. Open Marine Environment

The following ranges seem to display the most marked differences in faunal assemblage when the results of several studies are combined although many authors studied different areas and depths and suggested different depth zonation by biofacies.



**High-Energy Zone:**

Intertidal environment	(to 20 m <sub>±</sub> )
Inner neritic	(to 20 m <sub>±</sub> )
Middle Neritic	(20m <sub>±</sub> - 100m <sub>±</sub> )

**Lower-Energy Zone:**

Outer neritic	(100m <sub>±</sub> - 200m <sub>±</sub> )
Upper bathyal	(200m <sub>±</sub> - 500m <sub>±</sub> )
Lower bathyal	(500m <sub>±</sub> - 2000m <sub>±</sub> )
Abyssal	(>2000m <sub>±</sub> )

**Some Characteristics of Foraminiferal Ecology**

Faunal Distribution: Although similar environments of different localities contain similar faunal assemblages and species frequencies, the distribution of Foraminifera depends on the availability and frequency of species in an environment which is characterized by the geography, other organic assemblages, and undetermined local ecologic factors. There are very few species which are universal in distribution and the role of genetic processes are different in time and locality. However, patterning the distribution in the higher level of taxonomic rank is possible and predictable with reasonable probability within a relatively broader area, if the occurrence and frequency of fauna are expressed in broader terms. As previously discussed, depth and salinity are the dominating factors for such distributions.

Faunal Variability: It is reported from the studies of recent Foraminifera (Walton, 1964; Gibson and Buzas, 1973) that the number of benthonic species is inversely proportional to the variability of the environment. The

environment with many variable conditions, as in marginal marine or near shore areas, supports lesser numbers on benthonic Foraminifera than the relatively deep stable environments. The diversity is usually determined on the basis of the number of species of a counted or estimated foraminiferal population whose accumulative percentage constitutes 95% of the total population. This is practiced to eliminate the rare species or species of spotty occurrence. Validity of such a method should be tested by further study because the equitability of the species is also dependent on the depth. Therefore, it needs to be distinguished whether species diversity misrepresents the faunal trend to attain equal distribution among species assemblages in which the basic diversity remains unchanged. In general, the larger the sample studied the more species are encountered. However, if the species diversity is compared on a uniform basis some generalization can be made on the faunal diversity-environment relationship.

Faunal Dominance and Frequency: Faunal dominance is determined by the percentage of occurrence of the most dominant species in a sample population. This is known to be proportionally decreasing with depth and inversely proportional to the faunal variability; the percentage of the most dominant species in a sample of less faunal variety is greater than that of the most dominant species in a sample of greater faunal variability (Walton, 1964). Some higher frequency of a dominant species in the samples of greater

species diversity was attributed to the concentration by reworking. This can be detected in recent environments, provided the dynamics of such concentration is understood. However, this anomolous concentration would never be accurately accounted for in fossil assemblages in which the possibility of partial elimination of certain species with weaker wall structure by solution or selective biogenic destruction is possible. There have been no known studies yet to explain the nature of relative species frequency. Each species has its own optimum range of survival and reproduction. Productivity as expressed in frequency in the fauna varies widely.

Population Density: Because there are many factors that may influence the final concentration of the faunal assemblage, it is difficult to make any inference of environment on the basis of faunal density. Such factors as the rate of sedimentation, productivity of organisms, and destruction of tests by other organic or inorganic agents would decide the initial density and later diagenetic alternation and selective solution of the test would set the final size of fossil population. As long as the sample represents the original population with reasonable probability, the population density could be used to estimate the rate of sedimentation which may indirectly indicate the environment of deposition.

Shell Characteristics: It is commonly observed that there is a relationship between the environments and

characteristics of foraminiferal tests. Most of the investigations on shallow water Foraminifera concluded that arenaceous forms are always dominant in marginal marine environments where chemical elements are frequently diluted.

Walton (1964), from his observation on Gulf Coast foraminifers, indicated that the size and stoutness of calcareous tests also decrease toward the shallower marginal area and attributed this phenomena to the scarcity of necessary material for the test, noting usual larger and heavier tests in carbonate environments. This may not be correct because there are also deep water agglutinated species in significant number and heavier, larger tests are rather ubiquitous. In other groups of organisms, it seems to be a general trend of ecologic adaptation that heavier, stronger shells are needed in an environment of higher energy and greater ecologic variations. Therefore, it is difficult to generalize the test-environment relationship with chemical conditions alone. In order to see the overall distributional pattern of foraminiferal test types, the following table was generated from available data on Gulf Coast Foraminifera (Fig. 23). Tabulation was based on four major wall types represented by the genera. The number of genera in each environment is somewhat exaggerated by including all possible genera that are known to occur in the concerned environment and do not represent the average number of genera in the environments.

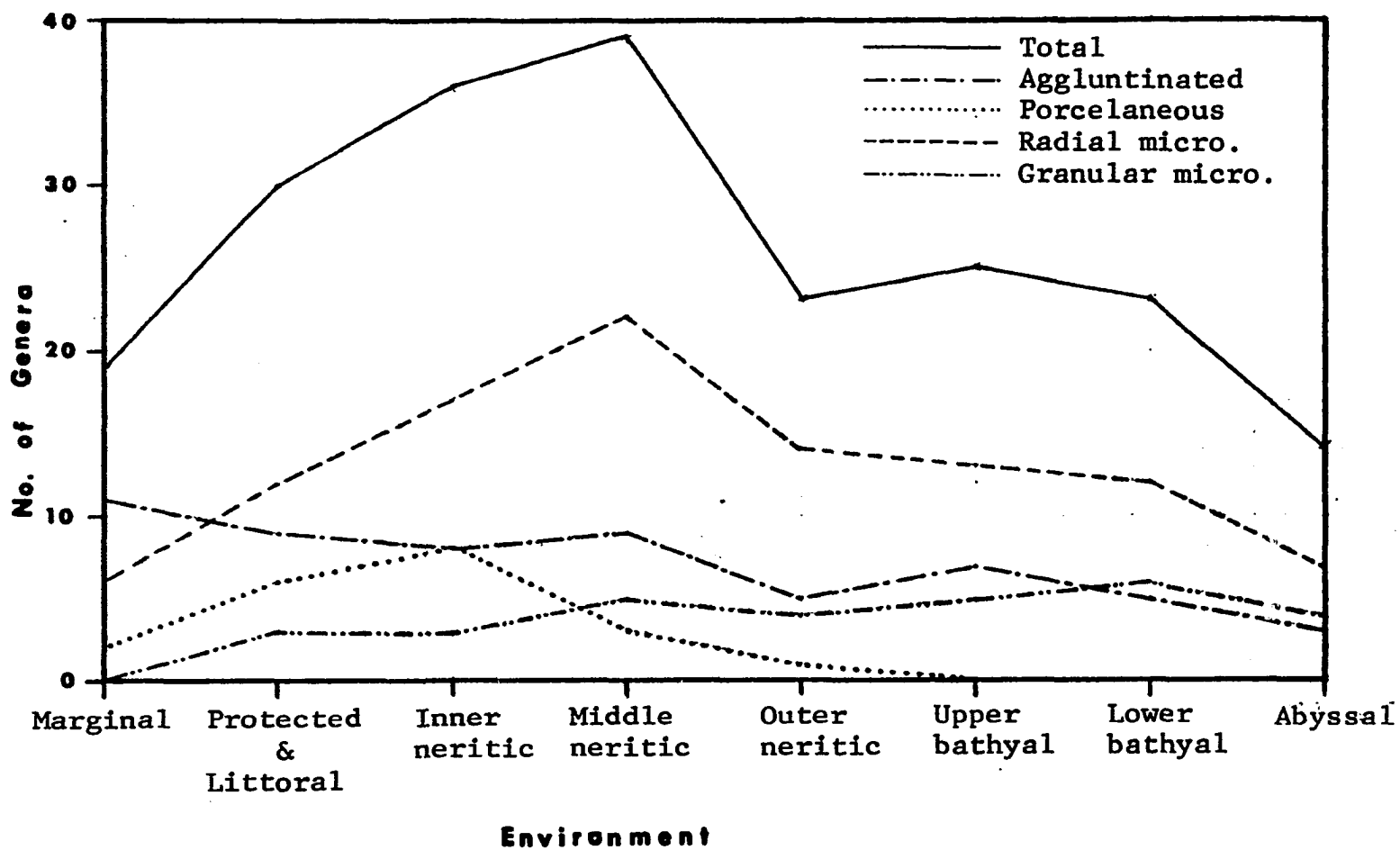


Fig. 23. Distribution of Recent Foraminiferal Genera by Wall Structure

While it is premature to make any conclusive statement from such a distribution, it is interesting to note that the dominance of agglutinated forms in marginal marine and that of porcelaneous forms in shallow marine are in accordance with previous findings. Also the number of genera with granular microstructure seems to increase toward deeper environments while that of radial microstructure follows closely the overall distribution of genera as it is the most dominant wall type. Such an approach may prove to be a useful criterium for the ecologic and environmental studies if systematically pursued further.

However, the quantitative character of such a distribution could not be evaluated because of the absence of such data in most ecologic studies from which the figures were drawn.

Planktonic Population: The relative frequency of planktonic Foraminifera, with respect to the benthonic fauna, is largely controlled by the density of benthonic Foraminifera within the population. The productivity of planktonic Foraminifera remains the same throughout most of the open marine conditions; however, dilution by other benthonic foraminifera determines the planktonic-benthonic ratio. It is generally true that the ratio between planktonic and benthonic foraminifera increases with the distance from the shoreline and increasing depth. However, there are great variations among samples of similar depths causing an unreliable prediction of depth by the planktonic-

benthonic ratio only. It is even more difficult in an ancient environment in which the rate of reproduction of planktonic foraminifera might have been different from that of the Holocene.

Assuming, therefore, that the conditions of paleo-depositional environments corresponds approximately to the Holocene, the ratio variation could be used to infer relative change of depth of the environment or distance of shore line from the basin. From bottom samples of the Gulf Coast Area, depth-ratio relationship were established by Grimsdale and Van Morkhoven (1955), to show variations of the planktonic population with depth as follows:

$$\text{Ratio} = \frac{\text{planktonic population}}{\text{total population}} \times 100$$

30m	< 5%	Inner neritic
50m	< 10%	
60m	10 < R < 20%	
70m	20 < R < 30%	Middle neritic
100m	30 < R < 40%	
200m	40 < R < 50%	Outer neritic
300m	40 < R < 50%	
400m	30 < R < 40%	Upper Bathyal
500m	40 < R < 50%	
600m	50 < R < 60%	
700m	60 < R < 80%	Lower Bathyal
1300m	> 90%	

## Generic Distribution of Recent Foraminifera in Generalized Environments of the Gulf of Mexico

Following is the distribution of foraminiferal genera in the Gulf of Mexico compiled from various sources based on the bathymetry and physiography of the environments. Only those ecologic data from the Gulf of Mexico studied by Bandy, 1954, 1956; Benda and Puri, 1962; Kane, 1962, Kornfeld, 1931; Lankford, 1959; Lehman, 1957; Loep, 1965; Lynts, 1962; Phleger, 1951a, 1951b, 1954, 1955, 1956, 1960; Post, 1951, Shifflett, 1961; Walton, 1960 and Warren, 1956, were used.

The frequency and depth distribution of individual species are summarized in the Appendix II. Whenever there is no direct measurement on the depth range of individual species available, direct reading of bathymetry was taken for the species from the range charts presented by authors mentioned above.

### I. Transitional Environments

A. Brackish environmenst (inland marsh, estuary, brackish lake, inner bay area)

Ammoastuta  
Ammobaculites  
Ammonia  
Ammoscalaria  
Ammotium  
Arenoparella  
Cribroelphidium  
Elphidium  
Eponides  
Haplaphragmoides  
Milliammina  
Miliolinella  
Palmerinella



Recurvoides  
 Reophax  
 Textularia  
 Triloculina  
 Trochammina

b. Protected marginal marine environment (sound, lagoon, outer bay area)

Ammobaculites  
 Ammodiscus  
 Ammonia  
 Ammoscalaria  
 Ammotium  
 Arenoparella  
 Bolivina  
 Buccella  
 Buliminella  
 Cibicides  
 Cribroelphidium  
 Discorbis  
 Elphidium  
 Eponidella  
 Gaudryna  
 Guttulina  
 Hanzawaia  
 Haplophragmoides  
 Hauerina  
 Massilina  
 Milliammina  
 Miliolinella  
 \*Nonion(Melonis)  
 Nonionella  
 Palmerinella  
 Quiqueloculina  
 Rotalia  
 Spiroloculina  
 Trochammina  
 Triloculina

## II. Open Marine Environments

a. Littoral environment (Delta edge, beach, intertidal, reef)

Ammobaculites  
 Ammonia  
 Arenoparella

\*genus also includes genus in parenthesis

Bigenerina  
 Bolivina'  
 Buliminella  
 Cancris  
 Cibicides  
 Cibicidina  
 Elphidium  
 Epistominella  
 Gaudryina  
 Fursenkoina  
 Haplophragmoides  
 Massilina  
 \*Nonion (Melonis)  
 Nonionella  
 Palmerinella  
 Quinqueloculina  
 Ammonia  
 Spirillina  
 Textularia  
 Triloculina  
 Trochammina

b. Inner Shelf (up to 20m)

Ammobaculites  
 Ammonia  
 Archaias  
 Asterigerina  
 Bifarina  
 Bigenerina  
 Bolivina  
 Buliminella  
 Cibicidina  
 Discorbis  
 Elphidium  
 Epistominella  
 Eponides  
 Fursenkoina  
 Gaudryina  
 Globulina  
 Guttulina  
 Hanwawaia  
 Lenticulina  
 Massilina  
 Nodobaculariella  
 Nonionella  
 Nouria  
 Peneroplis  
 Planulina  
 Pyrgo  
 Quinqueloculina  
 Reussella  
 Reophax

Ammonia  
 Spirillina  
 Textularia  
 Trochammina  
 Triloculina  
 Uvigerina  
 Wiesnerella

c. Middle Neritic (20+m - 100+m)

Ammobaculites  
 Amphistegina  
 Archaias  
 Asterigerina  
 Bifarina  
 Bigenerina  
 Bolivina  
 Bulimina  
 Bulliminella  
 Cancris  
 Cassidulina  
 Cibicides  
 Clavulina  
 Discorbis  
 Eggerella  
 Elphidium'  
 Epistominella  
 Eponides  
 Fursenkoina  
 Gaudryina  
 Hanzawaia  
 Lenticulina  
 Marginulina  
 \*Nonion (Melonis)  
 Nonionella  
 Nouria  
 Planobulina  
 Planulina  
 Pyrgo  
 Quinqueloculina  
 Reophax  
 Reussella  
 Ammonia  
 Siphonina  
 Textularia  
 Trifarina  
 Trochammina  
 Uvigerina  
 Valvulineria

d. Outer Neritic (100+m - 200+m)

Amphistagina

Bigenerina  
 Bolivina  
 Bulimina  
 Cassidulina  
 Cibicides  
 Clavulina  
 Discorbis  
 Eponides  
 Fursenkoina  
 Gaudryina  
 Hanzawaia  
 Lenticulina  
 Nodosaria  
 Planulina  
 Pullenia  
 Rectobolivina  
 Reophax  
 Sigmoina  
 Siphonina  
 Trifarina  
 Uvigerina  
 Valvulineria

e. Upper Bathyal (200+m - 500+m)

Bolivina  
 Bulimina  
 Cassidulina  
 Chilostomella  
 Cibicides  
 Clavulina  
 Cyclamina  
 Epistominella  
 Eponides  
 Fissulina  
 Fursenkoina  
 Glomospira  
 Gyroidinoides  
 Haplophragmoides  
 Karreriella  
 Lenticulina  
 Nodosaria  
 Planulina  
 Pullenia  
 Reophax  
 Ammonia  
 Trifarina  
 Trochammina  
 Uvigerina  
 Valvulineria

## f. Lower Bathyal (500+m - 2000+m)

Bolivina  
Vulimina  
Cassidulina  
Chilostomella  
Cibicides  
Cyclammina  
Eggerella  
Epistominella  
Eponides  
Fursenkoina  
Glomospira  
Gyroidina  
Haplophragmoides  
Laticarinina  
Lenticulina  
Osangularia  
Pullenia  
Rotalia  
Spaeroidina  
Trifarina  
Trochammina  
Uvigerina  
Valvulineria

## g. Abyssal (Depth 2000+m)

Bolivina  
Vulimina  
Eggerella  
Eponides  
Fursenkoina  
Glomospira  
Gyroidina  
Haplophragmoides  
Lenticulina  
Nodosaria  
Osangularia  
Planulina  
Pullenia  
Uvigerina

## PALEOECOLOGY

### General

Except for transitional marginal marine environments in which the physiographic arrangement of the environment is of greater importance than absolute depth of the basin, a marine ecologic environment is generally defined as the area which is characterized by the distribution of unique species or faunal assemblage (s) controlled by the depth of water. In this regard, foraminifera are the most frequently studied fauna because of their abundant occurrence and persistent geologic record.

Phleger (1960) summarized the distributional pattern of the Foraminifera as follows:

- 1) Discrete depth range of species
- 2) Mutually inclusive assemblage of species
- 3) Frequencies of species

In the studies of foraminiferal ecology, most of the authors use these criteria to define the ecologic environments.

In the following, some comparisons between Claiborne species and Holocene relatives were attempted to see if any common criteria can be drawn from present ecologic implications which are applicable to a paleoecologic interpretation.

Bathymetry and Environment of Some Important Claiborne  
Foraminiferas Compared with Holocene Species

Species of twenty-seven Claiborne genera, which occur in more than 5% of the total benthonic population, were chosen for paleoecologic evaluation. They were compared with recent species for bathymetric and environmental inferences. Species occurring in less than 5% were treated separately and considered to be insignificant unless there was a definite preference of environment. The frequency of living species could only be denoted in such generalized scale as very rare (less than 1%), rare (1 to 5%), common (5-20%), abundant (20-50%), and dominant (more than 50%). Recent works in foraminiferal ecology frequently adopted such a scale, because this method can reasonably summarize frequency variations in most cases.

The genetic relationship between genera or species and evolutionary trend of species was not systematically studied because of their irrelevancy to the objectives of the present study. However, some homeomorphic comparison between old and living species was made directly in an attempt to determine the most closely related morphospecies and their environmental implication.

Depth range of living species represent the range in which the species occur most commonly or constitute a significant part of an assemblage. Where the specific depth range was not available, a generalized environmental term was given for the species. (See Table of Appendix II)

Only those species occurring in more than 5% in an assemblage are evaluated. Herein, Cane River is abbreviated C. and Weches W. Percentage numbers show the maximum frequency for the genus with a total of all species where applicable:

Alabamina

Maximum Frequency: C: 18% W: 15%

Claiborne Species: A. wilcoxensis

There are no Alabamina species reported from present Gulf of Mexico environments. Alabamina has been confused with Eponides; however, there is no Holocene Eponides in the Gulf of Mexico which resembles Alabamina. It is concluded, therefore, that genus Alabamina is an unique fossil species, at least in the Gulf Coastal region.

In both formations, Alabamina species occur in both the glauconitic and clayey sections; however, they are not associated with arenaceous species of marginal marine environs. It is assumed, therefore, that within the depth range of the Cane River and Weches environments this species was not depth sensitive as long as the overall environment remained marine.

Ammobaculites

Maximum Frequency: C: 14% W: 6%

Claiborne Species: A. mauricensis

A. mauricensis is confined to the upper brown clay of



both formations which grades into non-fossiliferous silt or sand. Most of the living species of Ammobaculites occur with high frequency in transitional areas of subnormal salinity. It would appear, therefore, that species of Ammobaculites have remained in a similar environment, at least since the Eocene.

#### Anomalinoides

Maximum Frequency:	C: 49%	W: 9%
Claiborne Species:	<u>A. costianus</u>	
	<u>A. umbonatus</u>	

Anomalinoides species are more abundant in the Cane River Formation. The higher frequency of occurrence coincides with a high planktonic-benthonic ratio. It is assumed, therefore, that species of Anomalinoides are indicative of a deeper marine environment.

#### Asterigerina

Maximum Frequency:	C: 15%	W: 69%
Claiborne Species:	<u>A. texana</u>	

A. texana, extremely abundant in the Weches samples, is insignificant in the Cane River except in a few isolated samples. Holocene species also show a "spotty" but concentrated distribution within a relatively wide range of depth.

#### Bolivina and Brizalina

Maximum Frequency:	C: 21%	W: 3%
Claiborne Species:	<u>Bolivina gracilis</u>	
	<u>Brizalina taylori</u>	

Bolivina and Brizalina, minor constituents in the Claiborne assemblage, are more abundant in the Cane River

Formation. Based on studies of Holocene Foraminifera, these two genera appear to share similar ecologic niches, and are abundant in the deeper marine environments.

Some Holocene species of Bolivina have distinct and discrete range. When the overall frequency of total species is compared, relative to the depth alone, it is noted that the frequency of Bolivina species in a given assemblage is rare; however, they increase rather rapidly from middle neritic toward a deeper environment. A higher frequency of Bolivina and Brizalina specimens, therefore, is interpreted as an indicator of a deeper water environment.

#### Bulimina

Maximum Frequency: C: 18% W: 4%

Claiborne Species: B. byramensis  
B. truncana subsp. akusuatica

Living species of Bulimina generally are part of the deep water fauna which occur in the upper to lower bathyal environments.

#### Ceratobulimina

Maximum Frequency: C: 13% W: 25%

Claiborne Species: C. eximia

No living relative of the genus Ceratobulimina is known from the Recent Gulf Coast environment. Although it is not a dominant species, the relative frequency is much higher in the Weches samples.

#### "Cibicides"

Maximum Frequency: C: 38% W: 27%

Claiborne Species:                    C. pseudowuellerstorfi  
    C. mamiformis  
    C. lawi  
    C. mimulus

Most of the Holocene species are limited to the middle neritic to outer neritic environment. The overall generic diversity and frequencies are higher in the Cane River than in the Weches Formation.

### Cibicidina

Maximum Frequency:                    C: 15%                    W: 9%  
 Claiborne Species:                    C. mauricensis  
    C. westi

There is no Cibicidina species reported from the Gulf of Mexico environments. The species of Hanzawaia, therefore, are substituted for Cibicidina because of their morphologic similarity. All seem to be characteristic of inner to middle neritic depth. In the Claiborne assemblages, the occurrence of Cibicidina is closely related to "Cibicides".

### Cyclammina

Maximum Frequency:                    C: 3%                    W: 98%  
 Claiborne Species:                    C. cancellata obesa

In the present day environment, Cyclammina is strictly confined to the deeper water. A study by Robinson (1970) shows, however, that this genus, originally associated with a neritic assemblage, has migrated constantly toward the deeper environment since Miocene time. In the Claiborne, it is found in greater abundance associated with arenaceous forms of the transitional marginal environment; therefore, must be part of the transitional assemblage.

"Discorbis"

Maximum Frequency: C: 1% W: 51%  
 Claiborne Species: D. stenzeli  
D. yeguaensis

The depth range of those suspicious species of "Discorbis", sometimes identified as Eponides, show some differences because of their questionable generic assignment. The general depth of Holocene "Discorbis" species indicates that they occur in shallower than middle neritic environments. In Weches-Cane River time, "Discorbis" species were confined strictly to the Weches environment.

Globulina

Maximum Frequency: C: 3% W: 7%  
 Claiborne Species: G. gibba

No Globulina species has been reported from the Gulf of Mexico; therefore, the bathymetry of this genus can not be ascertained. Claiborne species of Globulina occur randomly throughout the samples without any significant variations.

Guttulina

Maximum Frequency: C: 5% W: 7%  
 Claiborne Species: G. irregularis

There was no report of Guttulina species from the examined sources on Gulf of Mexico Foraminifera. This genus occurs in both formations; however, in much greater frequency in the Weches Formation.

Gyroidinoides

Maximum Frequency: C: 29% W: 52%  
 Claiborne Species: G. octocameratus

Two closely related genera, Gyroidina and Gyroidinoides occur more abundantly in deep water environments. The Claiborne species, however, are more closely related to a very shallow environment. In a transgressive sequence, they immediately succeed brackish assemblages of arenaceous foraminifers and persist thereafter throughout the section. It is conceivable, therefore, that the species of Gyroidinoides gradually receded from the shallower environment and restricted itself to the deeper marine environment.

#### Haplophragmoides

Maximum Frequency:	C: 32%	W: 82%
Claiborne Species:	<u>H. canariensis</u> <u>H. compalanata</u> ( <u>Crisbrostomoides</u> according to L & T)	

Haplophragmoides species have been invariably a part of the marginal marine fauna except for the Holocene H. bradyi which occurs mainly in deep water.

#### Lamarckina

Maximum Frequency:	C: 18%	W: 46%
Claiborne Species:	<u>L. claibornensis</u>	

L. claibornensis is present, most dominantly, in the Weches section. The highest frequencies occur immediately adjacent to the brackish arenaceous assemblages. Although there is only one Lamarckina species which occurs rarely in the Holocene, this fossil species seem to have lived in a slightly deeper environment.

#### Lenticulina

Maximum Frequency:	C: 18%	W: 5%
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Claiborne Species: L. alatolimbata  
L. midwayensis

Claiborne species of Lenticulina, occurring sporadically throughout the sample examined, have a higher frequency of occurrence in the Cane River Formation. Holocene species seem to have a wide range of depth, therefore, the depth of Lenticulina species is undeterminable. However, it is more diverse and abundant in the Cane River which has a slightly deeper bathymetry than the Weches Formation.

### Melonis

Maximum Frequency: C: 9% W: 6%

Claiborne Species: M. planatus

In the Claiborne, Melonis accounts for a rather insignificant proportion of the total fauna. However, it occurs frequently throughout the normal marine sediments of both formations. In the Holocene environments of the Gulf of Mexico, the bathymetric distribution of this genus is determined by individual species much like the case of Bolivina. Obviously, this genus extended its depth range into shallow, transitional to as deep as bathyal or deeper environments.

### Neoeponides

Maximum Frequency: C: 14% W: 26%

Claiborne Species: N. mexicana

Because of their close relationship and previously less strict taxonomic differentiation, the species of Neoeponides and Eponides are combined here. In Holocene environments

they are generally regarded as deep water species. In the Claiborne formations, this genus occurs with a conspicuously higher frequency in the Weches outcrops.

#### Quinqueloculina

Maximum Frequency: C: 1% W: 51%

Claiborne Species: Q. claiborniana  
Q. yeguaensis

All species of Quinqueloculina are considered to be a part of the shallow water fauna. Quinqueloculina species are extremely abundant in the Weches Formation, and are absent in the Cane River Formation. In the Holocene environments, Quinqueloculina ranges from inner to middle neritic depth, and occurs more abundantly in the area of carbonate deposition. For example, the Florida shelf environment has a rich Quinqueloculina fauna; however, the Louisiana offshore shelf environment has a very reduced population of the genus Quinqueloculina. The distribution of Quinqueloculina in the two Claiborne formations can not be explained at this time.

#### Siphonina

Maximum Frequency: C: 41% W: 51%

Claiborne Species: S. claibornensis  
S. danvillensis

In the Claiborne formations, species of Siphonina occur very abundantly in the entire assemblages studied. Two Holocene species show a relatively wide depth range; however, they do not occur as abundantly as in the Claiborne. Some previous interpretations of Claiborne species (Curtis, 1955)

as being typically a deep water fauna are considered to be doubtful.

### Spiroplectamina

Maximum Frequency: C: 8% W: 18%

Claiborne Species: S. zapotensis

Spiroplectamina and Textularia, which are difficult to differentiate, are treated as a homeomorphic group. In recent environments, their depth of occurrence varies from inner to outer neritic. The Claiborne species also occur throughout the section without significant variation.

### Trifarina

Maximum Frequency: C: 18% W: 1%

Claiborne Species: T. wilcoxensis  
T. new species

Although not in great quantities, Claiborne species of Trifarina are concentrated in the Cane River samples. Only a few specimens were found from several samples in the Weches. Holocene species are insignificantly distributed without any specific depth preference. It appears, therefore, that the distribution of genus Trifarina is not controlled by the depth of water.

### Triloculina

Maximum Frequency: C: 0% W: 13%

Claiborne Species: T. paulocostata

Recent species of the genus Triloculina are dominantly shallow inner neritic. Their trend of occurrence in both the Holocene and Claiborne environments concur with the Quinqueloculina species; therefore, the species of both



genera all could be treated as a single taxon in the family miliolidae.

### Trochammia

Maximum Frequency:	C: 85%	W: 67%
Claiborne Species:	<u>T.</u> sp.	

There is some reservation herein as to the generic assignment of Claiborne species to the genus Trochammia because of the indistinctness of the aperture. It occurs exclusively in the transitional environments in the Cane River and Weches Formation.

### Turrilina

Maximum Frequency:	C: 6%	W: 1%
Claiborne Species:	<u>T. robertsi</u>	

The single species of the genus Turrilina is more common in the Cane River. It is not present in the Holocene of the Gulf of Mexico; therefore, its ecological implication can not be ascertained.

### Uvigerina

Maximum Frequency:	C: 8%	W: 1%
Claiborne Species:	<u>U. blancocostata</u> <u>U. garzaensis</u>	

Recent species of Uvigerina occur most commonly in the environment deeper than the middle neritic zone. Their occurrence in a shallower environment is very rare. In the Claiborne samples, species of Uvigerina occur in very low frequency; however, they are more abundant in the Cane River fauna.

Discocyclusina

Maximum Frequency: C: Abundant W: Absent

Claiborne Species: D. advena

Discocyclusina is the largest Foraminifera in the samples studied. It requires special attention as to the environmental condition it represents, because of its unique occurrence relative to living species of other larger Foraminifera in modern environments.

Most of the living species of larger Foraminifera are confined to the depth zone of 35 m or less. Also, larger Foraminifera are closely related to the distribution of marine flora, a pattern of distribution which closely resembles that of modern species of coral. A survival range of temperature for these species is limited to between 18° - 27° C. Although Discocyclusina has no living relatives, it may be assumed that this species also thrived in a similar shallow environmental condition in the Eocene where it was consistently associated with the oyster, Cubitostrea lisbonensis, which was also a member of a shallow water environment.

Based upon ecologic studies resulting in the interpretations given above, the paleoecology of certain foraminiferal genera are summarized as follows: 1) foraminifers which are considered to have remained in a similar environment since the Eocene:

Ammobaculites  
Bolivina and Brizalina  
Bulimina  
Cibicidina

Haplophragmoides  
Lenticulina  
Quinqueloculina  
Spiroplectamina  
Trifarina  
Uvigerina

2) Foraminifera which are considered to have adopted different environment since the Eocene:

Asterigerina: from inner Neritic to middle Neritic

Cibicides: from inner-middle Neritic to middle-outer Neritic

Cyclammina: from Transitional environment to UpperBathyal or deeper environment.

Discorbis: from inner Neritic to middle-outer Neritic environments

Gyroidinoides: from inner Neritic to deeper than outer Neritic environment

Lamarckina: from inner Neritic to Littoral environment

Melonis: from inner-middle Neritic to Transitional or bathyal or deeper environment

Neoeponides: from inner Neritic to outer Neritic or deeper environment

Siphonina: from inner-outer Neritic to middle Neritic to deeper environment

Trochammina: from Transitional environment to wider range of environment (Transitional, inner Neritic to Lower Bathyal)

3) Foraminifera not occurring in the present Gulf Coast environment but occur abundantly in the Claiborne stage.

Inferred environments are:

Alabamina: inner to middle Neritic

Anomalinoides: middle to outer Neritic

Ceratobulimina: inner to middle Neritic

## Environmental Assemblage

### General

Despite the fact that both formations have 79 species of Foraminifera in common, there are apparent differences between the two formations in diversity of assemblages.

It is apparent that the two formations examined in the present study are the results of deposition during the period of marine transgression and regression in the Lower Claiborne. Therefore, it is assumed that within the lithologic sequence of each formation this deepening and shallowing in the depositional area is reflected in the faunal assemblages. One of the objectives of this research program, therefore, is to ascertain whether or not the depth variation can be recognized within the lithologic sequence of both the Weches and Cane River formations by examining quantitative variation of foraminiferal taxa.

Following are the main foraminiferal taxa which constitute the major portion of the faunal assemblage:

#### Weches

##### Major

Asterigerina  
Cibicides  
Discorbis  
Gyroidinoides  
Lamarckina  
Siphonina  
Lituolidae  
Miliolidae

##### Minor

Alabamina  
Ceratobulimina  
Neoeponides

Cane RiverMajor

Anomalinoidea  
 Cibicides  
 Siphonina  
 Lituolidae

Minor

Alabamina  
 Asterigerina  
 Bolivina  
 Brizalina  
 Bulimina  
 Gyroidinoidea  
 Lamarckina  
 Lenticulina  
 Neoeponides  
 Trifarina  
 Uvigerina

Major taxa are those which, alone or in combinations of two or three, dominate the assemblage (more than 50% of the total fauna). In most instances the Cane River Assemblages can be distinguished from the Weches Assemblages by the absence or insignificance of the species which dominate the Weches assemblage. On the other hand, the Cane River Assemblage has a substantially higher ratio of planktonic species which are present in the Weches Assemblage only in insignificant numbers.

The most notable differences in benthonic faunas are the absence in the Cane River Formation of the species of Family Miliolidae and the genus "Discorbis" and the extreme rarity in the Weches Formation of Bolivina, Brizalina, Bulimina, Trifarina and Uvigerina species. Also, the mode of occurrence of the major foraminifers displays conspicuous difference. The Weches fauna shows short burst of prolificacy of certain genera and species in a relatively limited period of time. Such a trend is less apparent in the Cane River Formation where the major taxa remain stable throughout most of sample assemblages.

### Result of Cluster Analysis

The purpose of cluster analysis is to see if the foraminiferal characteristics of assemblages could be systematically categorized and such a categorized unit have any implication in view of stratigraphic and environmental distribution of the assemblages.

The result of the cluster analysis of Unweighted Pair-Group Method using Centroid Averaging (UPGMC) is shown in the Appendix V (B) and a simplified dendrogram is derived as shown in the Figure 24.

The numbers on the similarity scale in the original dendrogram given in Appendix V (B) is a mathematical derivative of the data used and have no absolute value. The numbers at the bottom row in the Figure 24 is for the convenience of presenting arbitrary group of assemblages originally defined by the cluster analysis.

Foraminiferal assemblages could be categorized into distinctive groups on the basis of degree of similarity in their quantitative faunal property.

The distribution of assemblages in the sections examined in shown in the Figure 25.

At first, entire sample assemblages can be separated into three large groups (Figure 24, A, B, C). The Group "C" is further subdivided because there is significant clustering of assemblages at the greater similarity level.

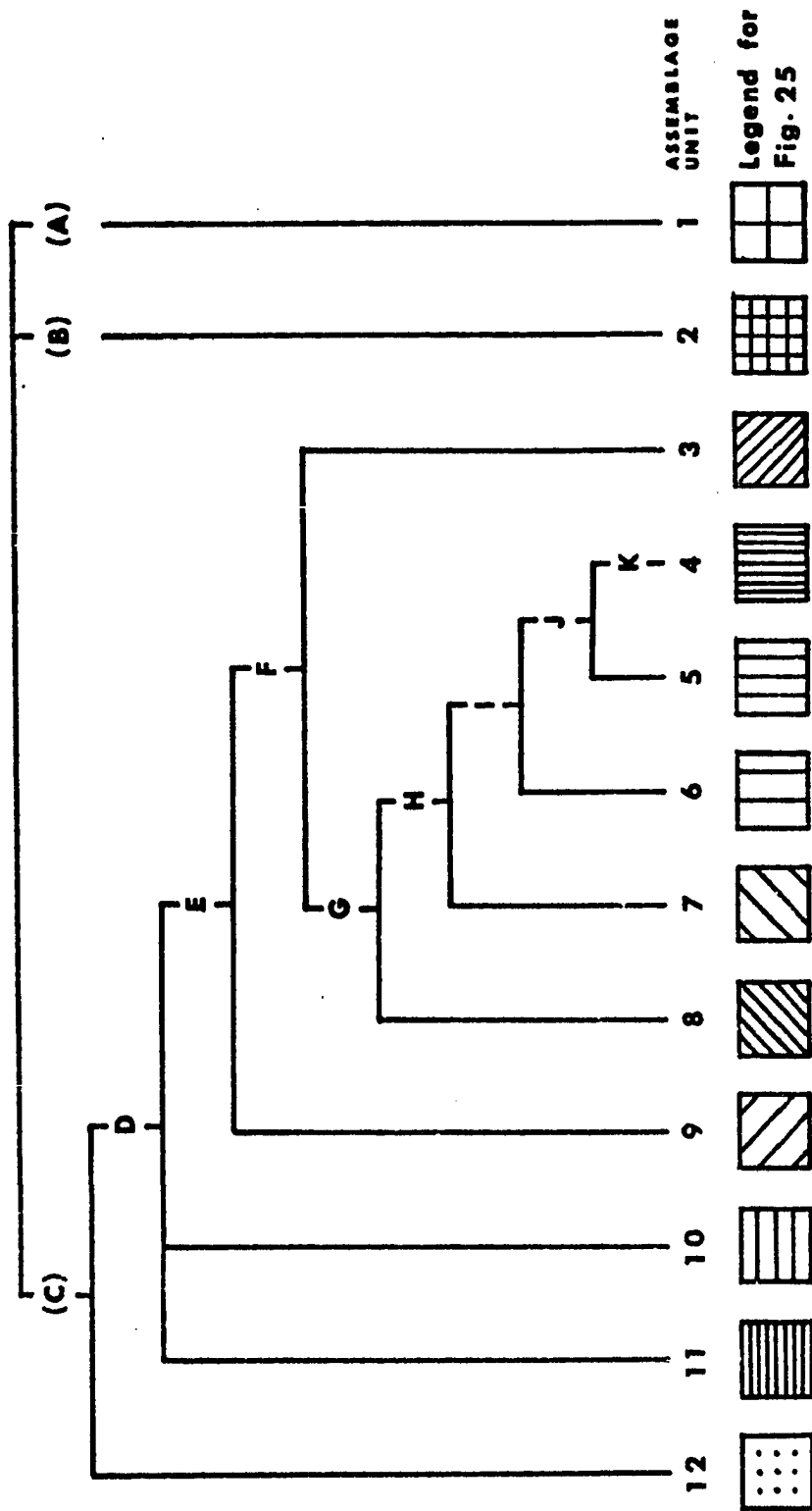
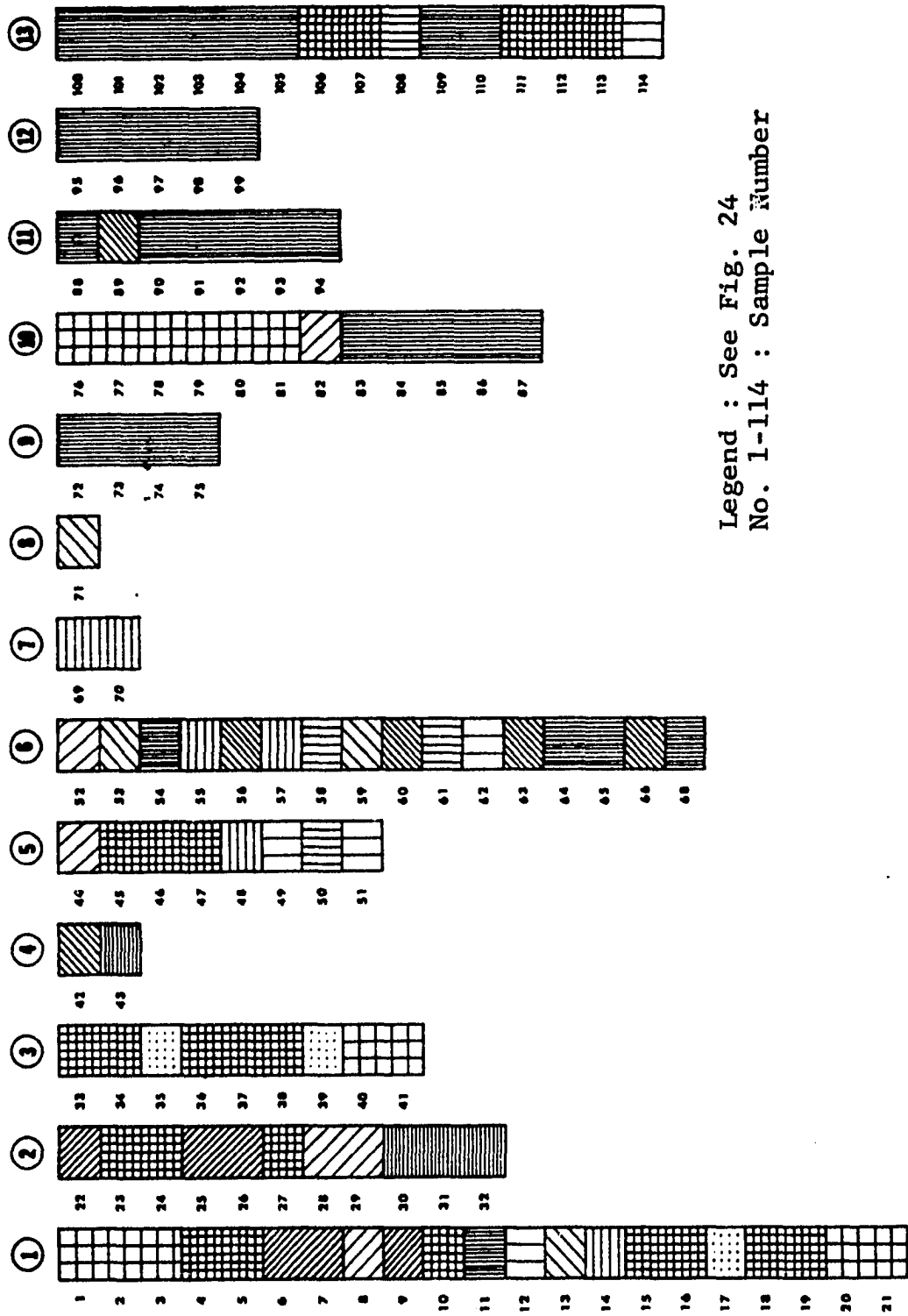


Fig. 24. Simplified Dendrogram of Assemblage Group



Legend : See Fig. 24  
No. 1-114 : Sample Number

Fig. 25. STRATIGRAPHIC DISTRIBUTION OF ASSEMBLAGE GROUP



Group "A" (Assemblage Unit 1)

Major Taxon	Minor Taxa
Lituolidae	Neoeponides Ceratobulimina Gyroidinoides Lamarckina Siphonina

This group consists mainly of arenaceous species of the Family Lituolidae. A very small number of minor species are also included in the assemblage; however, their proportion is insignificant. All of the 20 samples belonging to this group came from the marginal environment which represents the initial period of transgression and terminal stage of a true marine environment.

Group "B" (Assemblage Unit 2)

Major Taxa	Minor Taxa
Siphonina	Lenticulina
Lamarckina	"Cibicides"
Gyroidinoides	Alabamina
Discorbis	Globulina
Miliolidae	Neoeponides
Lituolidae	Asterigerina
	Anomalinoidea
	Spiroplectamina

This is the most heterogeneous group of assemblages in their constituent taxa and their frequency in the assemblage. Of 23 assemblages assigned to this group, 10 consist of less than 100 individuals. The Cane River assemblages belonging to this group were suspected of being abnormal because of some evidence of recrystallization

and destruction of original biogenic contents by diagenesis. On the whole, this group is distinguished by the overwhelming dominance of a few selected species in an assemblage and fewer number of species in the assemblage. The major species often occupy as much as 50% of the total population. Except for 5 samples from the Cane River, which show abnormal concentration of some species, this group is the characteristically Weches assemblage usually succeeding and surrendering to the arenaceous assemblages, respectively, in a transgressive and/or regressive sequence.

Group "C" (Assemblage Unit 3-12)

Major Taxa

Asterigerina  
Anomalinoïdes  
"Cibicides"  
"Discorbis"  
Gyroidinoïdes  
Lamarckina  
Miliolidae  
Siphonina  
Planktonics

Group "C" can be best classified as the assemblage of a normal marine environment, ranging from an assemblage with predominantly with species of Family Miliolidae to one with a high planktonic ratio.

Because there is so much variation within the group, it can be further divided into subgroups. In this subdivision, subgroups are hierarchilly promoted and each subgroup is inclusive of previous subgroup resulting in

more comprehensive environment (and assemblage group) as the rank of a subgroup increases. Therefore, the degree of similarity between faunal assemblages and environmental homogeneity decreases as the subgroup accumulates more members of assemblages.

Subgroup "K" (Assemblage Unit 4)

Major Taxa	Minor Taxa
Planktonics	Gyroidinoides
"Cibicides"	Alabamina
Anomalinoidea	Bolivina
Siphonina	Brizalina
	Lenticulina
	Lamarckina

This subgroup, consisting of 33 assemblages (of which 28 are from the Cane River Formation) probably represents the deepest environment in the area studied and is characteristic of the Cane River Formation.

Subgroup "J" (Assemblage Units 4, 5)

This group is essentially similar to the subgroup "E" except that the genus Asterigerina and the Family Miliolidae become important as the major foraminiferas along with minor species such as genera Neoeponides, Guttulina and Discorbis. This may indicate some variation in the environment of subgroup "K", possibly indicating a shallower part of the basin.

Subgroup "I" (Assemblage Unit 4-6)

Assemblages with the genera Ceratobulimina and

Uvigerina were added to the subgroup "I"; however, without much deviation from either subgroup "K" or subgroup "J". Adding these genera may be merely a faunal variation of the assemblage without any significant environmental implication.

Subgroup "H" (Assemblage Unit 4-7)

Four assemblages with high Miliolidae and Ceratobulimina content but without planktonics and Uvigerina promote the subgroup "I" up to the subgroup "H". This could be interpreted as further expansion of the environment formerly defined as subgroup "J".

Subgroup "G" (Assemblage Unit 4-8)

This subgroup includes six additional assemblages in which Asterigerina dominates the assemblage. This is considered to have wide range of depth and environment.

Subgroups "E", "F" (Assemblage Units 4-8, 4-9)

In these subgroups 12 assemblages characterized by the unique combination of Siphonina, "Cibicides", "Discorbis", Lamarckina and Ceratobulimina were included. Because these genera are already present in the previous assemblage, it may be just another spontaneous faunal variation in terms of their relative frequency in the assemblage. However, stratigraphically the added assemblages mark the upper part of the Weches Formation.

Subgroup "D" (Assemblage Unit 4-11)

Two more anomalous clusters of assemblages were included in the subgroup "D". An extraordinarily high frequency of Asterigerina, Lamarckina and Miliolidae characterizes these assemblages.

With the remaining few assemblages in which Gyroidinoides, Lamarckina, "Discorbis" and Lituolidae species form the major constituents, group "C" comprises almost two-thirds of all the samples examined.

Asterigerina, Ceratobulimina, "Discorbis", Gyroidinoides, and Lamarckina are practically controlling the assemblages which expand initial subgroup into later subgroup of lesser similarity.

## Comparison Between the Weches and Cane River Environments

This environmental interpretation of the Weches and Cane River Formations is based mainly on the foraminiferal assemblages supplemented with any other member of the fauna whenever available. As a sedimentary unit containing transgressive and regressive cycles, there are a number of environments in the Weches and Cane River Formations which reflect different stages of inundation. The most important environmental stage, however, is the time of maximum transgression which defines the inner boundary of the sedimentary regime. In these two Lower Claiborne units, glauconitic sediments are thought to represent such a condition.

Both formations possess transitional sections in which the major Foraminifera species are arenaceous. The species within this zone are quite similar in their relative frequencies and constituent species.

There are marked differences in the assemblages of the normal marine environment which constitute the major part of the two formations. Therefore, the resulting faunal statistics from these sections were expected to reflect the differences in basinal tectonics between the two formations in this deeper environment.

Following are some comparisons of foraminiferal statistics in the normal marine sections of the two formations:

	<u>Weches</u>	<u>Cane River</u>
Total No. of Benthonic Genera	40	61
Total No. of Benthonic Species	84	109
No. of Benthonic Genera occurring in more than 5% of total assemblage	22	24
No. of Benthonic Species occurring in more than 5% of the total population in an assemblage	27	30
Average No. of Genera per sample in the glauconitic sediments	13.5	20.3
Average No. of Species per sample in the glauconitic sediments	18.2	28.5
Average % of the most dominant species in the sample	35%	23.7%
Maximum frequency of the planktonic population among samples	13%	44%

Based on the ecologic criteria, above figures can be summarized as follows:

- 1) Diversity of species - increases in the deeper environment with Cane River greater than Weches
- 2) Degree of species equitability - increases in the deeper environment with Cane River greater than Weches
- 3) Frequency of the most dominant species - decreases in the deeper environment with Cane River less than Weches
- 4) Ratio of Planktonic/Total Population - increases in the deeper environment with Cane River greater than Weches.

The above summary suggests that the marine Cane River

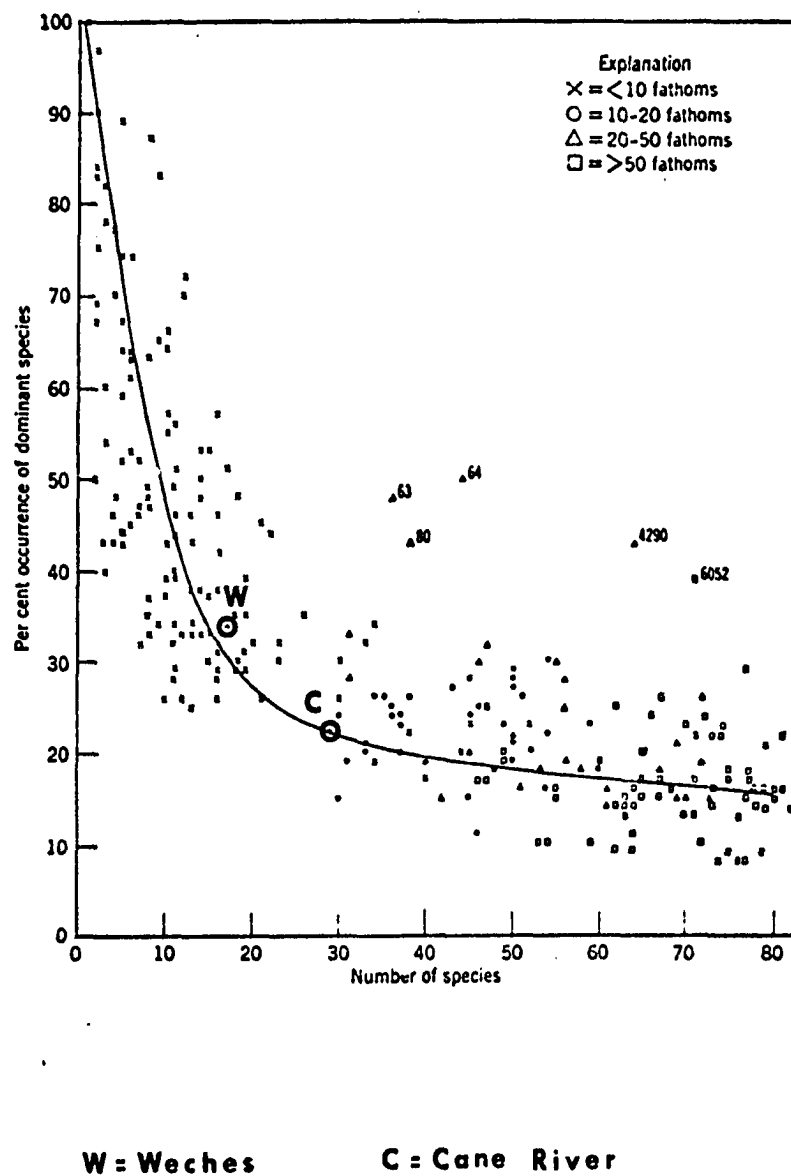


Fig. 26. Relationship between number of species and per cent dominance (Walton, 1964)



environment was relatively deeper than the Weches environment even without examining environmentally distinctive species.

In recent environment diversity of species and degree of species domination in a given assemblage also reflects bathymetric differences. When the statistics derived from the Claiborne samples were compared with the recent data (Walton, 1964). It was found that there is close correlation between Eocene and Holocene assemblages as shown in Figure 26 where the Weches and Cane River Foraminifera are plotted on Walton's distribution curve.

Walton (1964) concluded that the distribution of the samples on the curve, with regard to numbers of species and the depth of the samples, shows the following characteristics:

- "1. 100% of all faunas with less than 20 species occurs in water shallower than 10 fathoms.
2. 100% of all faunas with less than 30 species occurs in water shallower than 20 fathoms.
3. 80% of all faunas with 21 to 30 species occurs in water shallower than 10 fathoms.
4. 60% of all faunas with 31 to 40 species occurs between 10 and 20 fathoms (25%, less than 10 fathoms; 15%, 20 to 50 fathoms).
5. 46% of all faunas with 41 to 50 species occurs between 10 and 20 fathoms (7%, less than 10 fathoms; 29%, 20 to 50 fathoms; 18%, greater than 50 fathoms)
6. 36% of all faunas with 51 to 60 species occurs between 20 and 50 fathoms (4%, less than 10 fathoms; 26%, 20 to

50 fathoms; 23%, greater than 50 fathoms; 4%, greater than 50 fathom reefs)

7. 68% of all faunas with 61 to 70 species occurs deeper than 50 fathoms (7%, 10 to 20 fathoms; 26%, 20 to 50 fathoms)
8. 91% of all faunas with 71 to 80 species occurs deeper than 50 fathoms (9%, 20 to 50 fathoms), thus 100% of all faunas with more than 71 species occurs deeper than 20 fathoms.
9. 100% of all faunas with more than 81 species occurs deeper than 50 fathoms."

(Walton, 1964, p. 217)

The following are the relationship between percent dominance of a species and depth of the sample.

- "1. 100% of all faunas whose dominant species constitutes over 35% of the entire fauna occurs shallower than 10 fathoms.
2. 36% of all faunas with dominant species constituting 21% to 30% occurs between 10 and 20 fathoms (31%, less than 10 fathoms; 13%, from 20 to 50 fathoms; 21%, deeper than 50 fathoms)
3. 57% of all faunas with dominant species constituting 11% to 20% of the fauna occurs deeper than 50 fathoms (4%, less than 10 fathoms; 18%, 10 to 20 fathoms; 20%, 20 to 50 fathoms)
4. 92% of all faunas with dominant species constituting less

than 10% of the fauna occurs deeper than 50 fathoms (8%, from 20 to 50 fathoms)."

Diversity of the dominant species is also greater in the Weches Formation, possibly indicating ecologically unstable condition of the basin. In the Weches assemblages, species of Asterigerina, "Cibicides", "Discorbis", Gyroidinoides, Lamarckina, Quinqueloculina and Siphonina compete against each other for the dominance in the faunal assemblage, while in the Cane River, Anomalinoidea, "Cibicides" and Siphonina form the major portion of the assemblage with compatible proportions.

Should the bathymetry be inferred strictly on the basis of species diversity and dominance, the average Weches environment has never been deeper than 10 fathoms. (This is approximately the maximum depth ( $20 \pm m$ ) of the inner neritic zone as defined in the present study.) On the same basis, the Cane River environment could have been anywhere from the inner neritic to the outer neritic but more probably middle to outer neritic. The relative percentage of planktonic species also suggests that the Weches Formation was mostly under inner neritic conditions (planktonic/ total population ratio = less than 5%) except in the middle portion of the section, where, for a brief period of time, up to 13% of the planktonic population observed indicates a period of middle neritic deposition (at least on the basis of planktonic foraminifers). In the Cane River Formation, the population of planktonic Foraminifera varies but maintains

a relatively high frequency in the glauconitic sections (up to 44%). This indicates at least a middle neritic environment often including outer neritic depth also.

The following genera, found to be common at shallow depth in Holocene environments, are very abundant in the Weches Formation but are absent or occur rarely in the Cane River Formation.

Asterigerina  
Discorbis  
Lamarckina  
Quinqueloculina  
Triloculina

The following genera commonly occurring only in the Cane River Formation. They are generally considered to be indications of a deep water facies.

Bolivina  
Brizalina  
Bulimina  
Uvigerina

Related species to the above group, such as Siphouvigerina, Turrilina, Robertina and Trifarina, are also more abundant in the Cane River environment.

This study of the Weches and Cane River faunal groups also reveals that there is a lateral discontinuity in the pattern of foraminiferal distribution. This contradicts the former theory of basinal continuity between the Weches and Cane River environments which has long been accepted as the correct relationship between the two formations.

The foraminiferal genera and species listed as commonly occurring in each formation show considerable lateral persistence within the individual formation. When those genera

are compared in terms of frequency between the Weches and Cane River formations the following trend can be noted.

From Cane River to Weches:

<u>Anomalinoidea</u>	decreased
<u>Asterigerina</u>	increased
<u>Ceratobulimina</u>	increased
<u>"Cibicides"</u>	decreased
<u>"Discorbis"</u>	increased from 0%
<u>Gyrogoninoides</u>	increased
<u>Lamarckina</u>	increased
<u>Quinqueloculina</u>	increased from 0%
<u>Siphonina</u>	remained in similar frequency

The general trend is that those of deep water genera (Cane River taxa) decreased; those of shallower species (Weches taxa) increased. This variation in the two environments, Cane River and Weches, should imply: 1) that the species were so depth sensitive in Eocene time that they were more prosperous in their preferred depth environment; or, 2) that the population maturity of individual species had peaked during the time of either environment; or, 3) that there was an environmental constriction between the two areas that prevented equal distribution of the species. None of these hypotheses can be ruled out as a possible cause for such a trend; however, the latter two alternatives seem to be a more probable explanation for such faunal characteristic, which necessarily required separation of the two basins by either time or space or both.

Ostracoda species could not be systematically analyzed to prove any environmental differences because of the lack of ecologic information on the Ostracoda. However, there are apparent differences in their overall occurrence and frequencies of individual species as noted in the previous discussion on Ostracoda fauna. These differences were tentatively interpreted as the reflection of basinal differences between the two formations either in time or spatial relation. Burrowed zones are more common in the Weches section than in the Cane River section.

On the basis of all combined criteria it is concluded that the Weches sedimentary basin was mostly within the inner neritic zone while the Cane River sedimentary environment was within the middle to outer neritic zone. It is also assumed that the two basins were under two physically and chronologically separated environments in which different types of biologic organization have resulted.

Such a possibility is explained in the succeeding chapter.

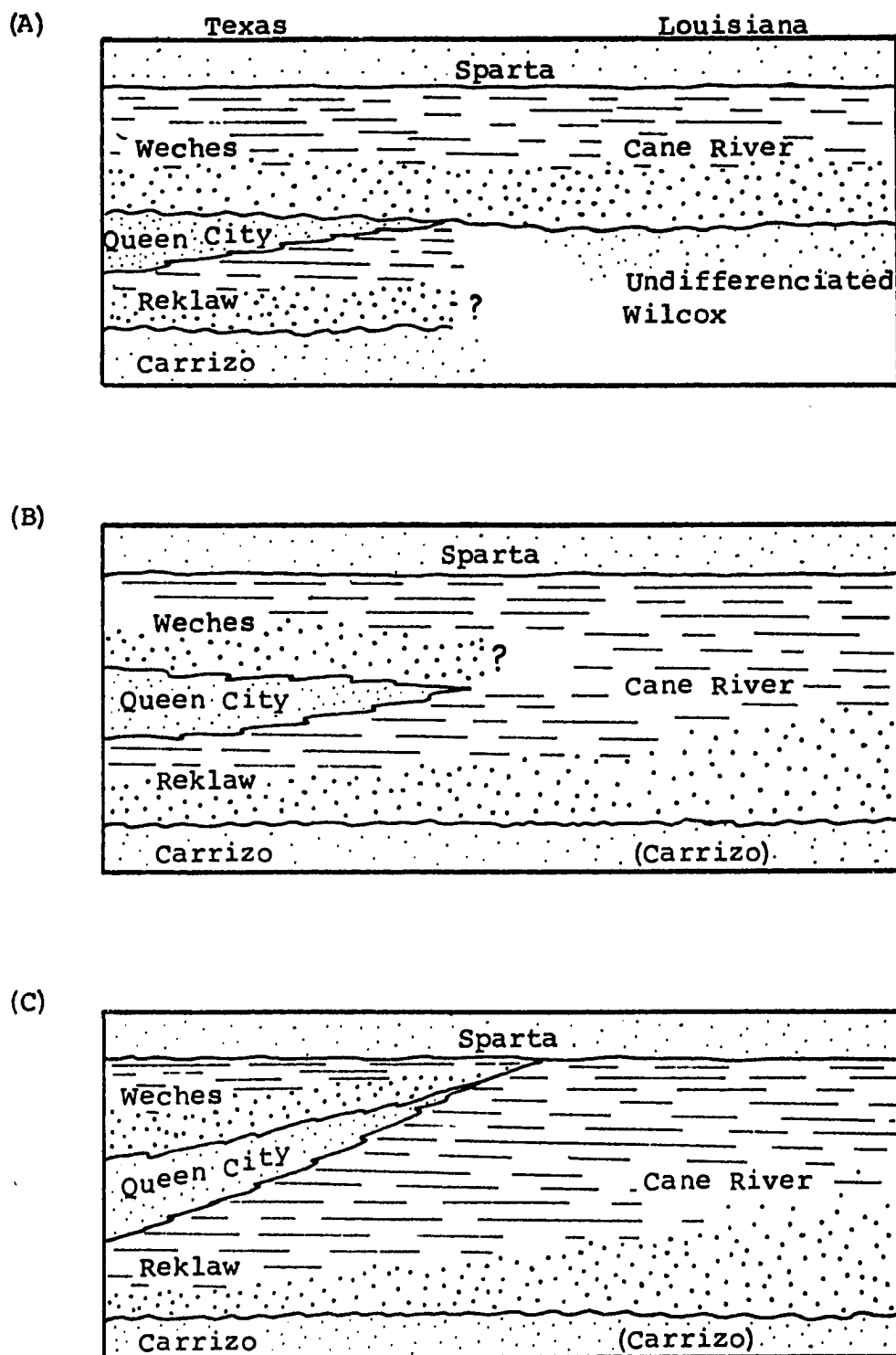


Fig. 27. Conceptual stratigraphic correlations between the Lower Claiborne Formations in the vicinity of West Louisiana and East Texas

## STRATIGRAPHIC CORRELATION

### Lithostratigraphy

The fundamental similarities of Gulf Coast Claiborne formations in lithology and sedimentary sequence is the result of periodic marine transgressions and regressions. The transgressive unit is generally characterized by a basal glauconite and an upper clay, while the regressive unit consists of widespread sands. This sequence has often been referred to as the Eocene sedimentary cycle in which the Reklaw - Queen City, Weches - Sparta, and Cook Mountain - Cockfield have been considered typical. Regional stratigraphy, based on the transgression-regression sedimentary concept, has been widely accepted for its apparent agreement in field observations despite frequent discontinuities. For the peculiar relationship between early Claiborne formations in east Texas and west Louisiana, however, two different correlations have been proposed, neither of which can be fully substantiated in this study either lithologically or biostratigraphically.

One correlation as initially conceived (Figure 27 (A)), is that the Cane River and Weches are time lithostratigraphically equivalent units constituting the transgressive portion of the Weches-Sparta cycle (Murray, 1961). The underlying Queen City and Reklaw were thought to form another cycle by themselves. The immediate difficulty for such a



correlation, however, is the necessity of delineating the Reklaw-Queen City cycle into comparable units below the Cane River in Louisiana. The Queen City Formation is known to be thinning eastward along its strike and pinches out in the subsurface just west of the Texas-Louisiana boundary. The Reklaw Formation, on the other hand, shows no tendency to decrease its thickness toward the east, maintaining a glauconitic-clay sequence throughout east Texas. Also, it has been demonstrated in many subsurface sections, that the undifferentiated units below the Cane River Formation in west Louisiana consist mainly of a thick sand without conspicuous glauconite and clay units, which belong either to the Upper Wilcox or Carrizo Formation. Therefore, a Reklaw-Queen City cycle seems to be improbable and, in fact, was not seriously considered as the correct relationship between the two formations except by a few authors, and is certainly not a considered opinion in this study.

The most widely accepted theory relative to the Weches-Cane River relationship is that the Reklaw, Queen City, and Weches together are equivalent to the Cane River (Figure 27 (B)). In this theory, the Queen City, a deltaic unit, is thought to be strictly a Texas formation which interrupted the marine environments of the Reklaw and Weches Formations. In this sequence, from the base of the Reklaw to the top of the Weches, sedimentary environments were interpreted as having shifted laterally, producing an irregularly deposited lithic facies horizontally along the margin of the depositional

basin with the Reklaw glauconite being a shelf facies, the Reklaw clay a prodelta clay facies, the Queen City a deltaic facies, the Weches glauconite again a shelf facies, and the Weches clay another prodelta clay facies. The Reklaw and Weches would then merge to form a single unit to the east in the vicinity of the Texas-Louisiana boundary where, collectively, they have been designated as the Cane River Formation. This concludes, in essence, that the sedimentary units bounded by the Carrizo (or its equivalent in Louisiana) at the base, and the Sparta Sand at the top, are time stratigraphic equivalents, and that the sediments in between are equally time stratigraphic equivalents. This is true except for a difficulty in relating different sedimentary facies between Texas and Louisiana because of the greater variety of sedimentary facies in the Texas units. It seems natural to relate the basal glauconite of the Reklaw to that of the Cane River and their upper clay units in the same manner. However, it is difficult to explain the status of the Weches basal glauconite at the point of Weches-Reklaw mergence because there is no additional glauconite unit in the Cane River which would be equivalent to the Weches glauconite. Because the glauconite is a product of typical marine environment and laterally persistent in all Claiborne units, it is difficult to explain why such a unit would disappear suddenly in the middle of a marine environment.

Also, their mode of mergence is incorrect if normal marine environment deepens toward the Cane River, because

it contends that shallowing (Upper Reklaw) and deepening (Lower Weches) occur simultaneously at the point of mergence.

Guevara and Carcia (1972) proposed that the Queen City is a complex of deltaic sediment prograding gulfward from different sources, and at different times in the Claiborne. It is possible, therefore, that the outcrop area south of the Sabine Uplift remained a positive element in a later period of time due to the sediment deposited during Queen City time which acted as a barrier between the Weches and Cane River environments. In other words, a marine transgression proceeded eastward after Queen City progradation, leaving the western part of the Weches in Texas partially equivalent to the Cane River in time. But before the area south of the Sabine Uplift reached normal marine conditions, non-marine sediments of the Sparta Formation began to construct another blanket of sand over the entire area, thus ending marine sedimentation both in Texas and Louisiana. This, in effect, suggests that the Weches sea had never been connected with the Cane River sea in the outcrop area near the Louisiana-Texas boundary, and, therefore, the Cane River is most nearly correlative with the Reklaw Formation in terms of time and lithologic continuity. This alternative is shown in Figure 27 (C).

Another speculative reason to believe that there existed some environmental barrier between the two formations in the unique distributional pattern of Queen City sediments in east Texas. This deltaic mass, so widely distributed only

in the area to the west of the Sabine Uplift, is also known to be traceable around the north of the Sabine Uplift, but never shows any sign of sandy influence on the Cane River sequence. This suggests two possibilities: 1) that the ancient ocean current was trending east to west along the coastline preventing any sand migration to the east (into the Cane River basin); or 2) that there was a physical barrier extending between the two basins which may have been a part of the southern portion of the Sabine Uplift since the beginning of the Queen City sedimentation.

Such a correlation was once proposed by Ellisor (1929) in which she suggested that the Weches pinched out between the Sparta and the Cane River (Reklaw of Ellisor at the time). She designated the lower section of the glauconitic Reklaw as the Cane River because of their traceability in the subsurface and paleontologic similarity. As it is believed that the migration of deltaic deposition, not eustatic change of sea level, resulted in shifting depositional environments during the Eocene, the alternative suggested in this study may well be the most acceptable explanation for the stratigraphic relationship between the Weches and Cane River formations.

### Biostratigraphy

Because the Weches and Cane River Formations are so closely related in time, with nearly identical lithologic sequences and faunal associations which show similarity,

two units may be regarded as contemporaneous in a broader sense.

The planktonic species of Foraminifera which are commonly used as the index fossil of the Claiborne also show similar occurrence in both formations, as expected, because zonations based on the planktonic species are generally too broad to detect any minor stratigraphic difference. However, some notable differences can be recognized in terms of relative position of a few important species in each formation and their unique association with other species.

Among all faunal characteristics which may be stratigraphically important, species of Cubitostrea show the most unique occurrence in the two formations. C. lisbonensis in the Weches always occurs in the lower part of the section. However, in the Cane River section it is characteristically present at a considerably higher level in the section marking the boundary between a predominantly glauconitic unit and the upper clay unit. Furthermore, the C. lisbonensis zone in the Cane River is always associated with the larger Foraminifer species Discocyclina advena. The Discocyclina advena zone has also been reported, frequently, in the Reklaw Formation in Texas but it never occurs in the Weches Formation.

The other oyster species, Cubitostrea smithvillensis which occurs only in the upper Weches Section, is absent in the Cane River section. Because the lower limit of each formation is confined by sand units of two different ages,

the above clues are concluded to place the Weches stratigraphically higher than the Cane River Formation, thus correlating the lower glauconitic section (Tyus member) of the Weches with the upper part of the Cane River. If the differences in the frequency of the major species in the two formations are time-stratigraphically controlled, as suggested in the Environmental Comparison, all the above faunal characteristics support the above proposed stratigraphic arrangement.

This conclusion coincides with the previously suggested idea of migrating environments. Since Discocyclina occurs in the Reklaw Formation in Texas, the Discocyclina zone in the Cane River Formation must be older than the Queen City of East Texas. After the appearance of D. advena, the Cane River environment also began to shoal while the deltaic Queen City sand was being deposited farther in East Texas. Eventually, and shortly after Cubitostrea lisbonensis moved into the shallowing Cane River basin. Later C. lisbonensis also appeared in the Weches sea which was regaining its territory from the then receding Queen City. After this interval of the Queen City sedimentation, the Weches environment (that part of the East Texas Embayment) was deepening while the Cane River basin (North Louisiana Syncline) was shallowing.

Species of Asterigerina, Lamarckina and Neoeponides began their appearance in appreciable quantity only in the latter stage of the Cane River environment. These species

merge as the dominant species in the lower Weches assemblages along with Discorbis and miliolids which were not yet present in the Cane River environment.

The absence of Discorbis and miliolids may be regarded as the result of bathymetric difference between the two formations. However, the inferred depth of the Cane River sedimentary basin (middle to outer neritic) is well within the tolerance limit of the two taxa. Therefore, the only feasible interpretation of such an occurrence is that there is a stratigraphic gap between the Weches and Cane River formations. Differences in the distribution of the Ostracoda species also seem to indicate the possibility of time stratigraphic difference in the same manner as the foraminiferal distribution in the two formations.

It is concluded, therefore, that the Cane River and the Reklaw formations are lithostratigraphically equivalent units while only the upper part of the Cane River is correlative with the entire Weches Formation time-stratigraphically.

Numerous subzones within each formation, on the basis of different foraminiferal species, are rather meaningless because they are neither particularly indicative of a certain environment nor laterally persistent in frequency nor discretely ranging vertically to mark any unique horizon. However, when the species are included in an assemblage their occurrence and relative abundance in relation with other taxa would generalize the subzones (or faunal zone) within the Formation. These were presented in the environmental assemblages and faunal distributions of previous chapters.

## CONCLUSIONS

1. It is inferred that there was a physical barrier between the Cane River and Weches depositional basins at their updip or northern margins near the Louisiana-Texas line. A physical change which resulted in the deposition of the Queen City non-marine sediments between marine Reklaw and Weches in East Texas could have been responsible for isolating these two basins.
2. The paleoecologic interpretation of Eocene Foraminifera, based on ecologic studies of living genera, proved to be reasonably reliable in reconstructing paleoenvironmental conditions in the Cane River and Weches Formations. On the whole, the bathymetry of most of the foraminiferal genera studied have remained essentially unchanged since the Eocene. Using these data in a quantitative analysis, the foraminifers revealed numerous biofacies within the two formations studied, which, in turn, lead to the following interpretations:
  - a) that the bathymetry of the Cane River depositional basin is estimated to have been between 20 to 100 meters during most of its sedimentary cycle; however, during its time of maximum transgression the water may have been as deep as 200 meters (in the outer neritic zone); and
  - b) that the Weches basin is inferred to have had a depth of less than 20 meters (inner neritic zone) throughout its depositional cycle.



In general, Cane River sediment was deposited in deeper water than the Weches sediment of equivalent ages.

3. It is proposed herein that the Cane River Formation is lithostratigraphically equivalent to the Reklaw Formation, and that only the upper part of the Cane River Formation is time-stratigraphically equivalent to the Weches Formation.

4. As a result of the taxonomic reexamination of the Weches and Cane River foraminiferal faunas, the following genera are regarded to have four undescribed species and one subspecies.

Ammobaculoides

"Cibicides"

Elphidium

Lenticulina pseudosecan

Trifarina

## PART II. TAXONOMY OF FORAMINIFERA

### SYSTEMATIC DESCRIPTION OF CANE RIVER AND WECHES FORAMINIFERA

A total of 144 species of 72 genera have been described from the samples of Weches and Cane River formations examined in this study. Four new species and one new subspecies were described. A total of 48 species which had been described as new species originally from the Cane River Formation were identified as synonyms of previously described species.

In reassigning the previously described species from the Cane River, each holotype and topotype were reexamined and compared with other pertinent type specimens preserved in the Museum of Geoscience of Louisiana State University.

Treatise of Invertebrate Paleontology (C) Protista was used for generic identification and Catalogue of Foraminifera (The American Museum of Natural History) was used for specific identification.

## SYSTEMATICS

## ORDER FORAMINIFERIDA

## SUBORDER TEXTULARIINA

Family Ammodiscidae Reuss, 1862

Genus Ammodiscus Reuss, 1862

Ammodiscus incertus (d'Orbigny)

Plate 1, Figure 1

Operculina incertus d'Orbigny, 1839, Foram. Cuba, p. 71,  
pl. 6, figs. 16, 17

Test finely arenaceous, cyclogyrine tubular coil gradually increases in size; slightly concave bilaterally; aperture an open end. Diameter: up to .25 mm.

Family Lituolidae de Bainville, 1825

Genus Haplophragmoides Cushman, 1910

Haplophragmoides canariensis (d'Orbigny)

Plate 1, Figure 2

Nonionina canariensis d'Orbigny, 1839, Foram. les canaries,  
p. 128, pl. 2, figs. 33, 34.

Test coarsely arenaceous; periphery lobulate, sub-acutely rounded; chambers about 6 in the final whorl, increasing rapidly in size, last two chambers slightly inflated; sutures distinctly depressed, almost straight; aperture equatorial slit at the base of the last chamber. Diameter: up to .34 mm.

Genus Cribrostomoides Cushman, 1910

Cribrostomoides complanatus (Hussey)

Plate 1, Figure 3

Haplophragmoides complanata Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 118, pl. 26, fig. 1.

Test finely arenaceous, much compressed, biumblicate; periphery sharply angled, faintly carinate; chambers 6-7 in the adult coil; sutures depressed, straight or very slightly curved near the periphery; aperture area, ovate opening located slightly above the base of the last chamber with faint but distinct rim. Diameter: up to .42 mm.

Remarks: Hussey described the aperture as being "simple arched slit at the base of the apertural face." However, the holotype and topotypes do not confirm this statement.

Genus Cyclammina Brady, 1876

Cyclammina cancellata Brady subsp. obesa

Cushman and Laiming

Plate 1, Figure 4

Cyclammina cancellata Brady var. obesa, Cushman and Laiming, 1931, Jour. Pal. Vol. 5, no. 2, 1931, p. 24, figs. 10 a-b.

Cyclammina caneriverensis Hussey, Jour. Pal., Vol. 17, no. 2, 1943, p. 160, pl. 26, fig. 12.

Test nautiloid, finely arenaceous, subglobose, planispiral, biumblicate, subcircular in outline; both sides somewhat flattened; periphery broadly rounded; chambers about 9 in the final whorl, increasing gradually in size; sutures radial, almost straight, depressed, aperture low equatorial slit at the base of the last chamber and small areal openings on the apertural face. Diameter: up to .6 mm.

Remarks: The type figure and description of C. caneriverensis exactly coincide with those of C. cancellata var. obesa.

Genus *Ammobaculites* Cushman, 1910*Ammobaculites mauricensis* Howe

## Plate 1, Figure 5

*Ammobaculites mauricensis* Howe, 1939, Louisiana Dept. of Conservation, Geol. Bull., no. 14, p. 30, pl. 1, figs. 13-14.

Test coarsely arenaceous, compressed; early chambers coiled, later ones uncoiled in a uniserial series; slightly biumblicate; sutures indistinct; aperture elliptical opening, terminal. Length: up to .45 mm.

Genus *Ammobaculoides* Plummer, 1932*Ammobaculoides*, new species

## Plate 1, Figure 6

Test coarsely arenaceous; large planispiral stage followed by loosely arranged biserial stage with tendency to become uniserial; uniserial stage consists of the last chamber; overall tear-drop shaped; periphery round; slightly biumblicate; sutures indistinct but slightly depressed; aperture indistinct, terminal. Length: up to .30 mm. Diameter of planispiral stage: up to .12 mm.

## Family Textulariidae Ehrenberg, 1838

Genus *Spiroplectammina* Cushman, 1927*Spiroplectammina plummerae* (Lalicker)

## Plate 1, Figure 7

*Textularia plummerae* Lalicker, 1935, Contr. Cushman Lab., Foram., Res. Vol. 11, pt. 2, p. 50, pl. 6, fig. 10.

*Plectamina regularis* Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 119, pl. 26, figs. 3-4.

Test elongate, slightly compressed, initial stage very small and coiled, biserial in adult; periphery rounded; wall rather coarsely arenaceous; chambers numerous, slightly inflated; sutures distinct, straight, oblique toward the initial end; depressed; aperture small arch at the base of the last chamber. Length: up to 1. mm.

Remarks: Hussey's P. regularis was erroneously described as having terminal aperture. Holotype specimen has small interiomarginal arch at the base of the last chamber.

Spiroplectamina zapotensis (Cole)

Plate 1, Figure 8

Textularia mexicana Cole (not Cushman), 1927, Bull. Am. Pal., Vol. 14, no. 51, p. 11, pl. 5, fig. 5.

Textularia zapotensis Cole, 1929, Corrigenda slip to same publication. T. mexicana was preoccupied.

Test finely arenaceous, strongly tapering toward initial end, broadest across the last two chambers; periphery acutely angled often with slight keel; sutures distinct, broadly depressed; aperture a low arch at the base of the last chamber. Length: up to .42 mm. Width: up to .28 mm.

Genus Textularia DeFrance in de Blainville, 1824

Textularia claibornensis Weinzierl and Applin

Textularia claibornensis Weinzierl and Applin, 1929, Jour. Pal., Vol. 3, p. 393, pl. 44, fig. 1.

Test finely arenaceous, elongate, slightly compressed, broadest across the last two chambers; periphery subacutely rounded, later chambers somewhat inflated; sutures indistinct in early portion, depressed in later portion; aperture low interiomarginal arch. Length: up to .8 mm. Width: up to .31 mm.

## Family Trochamminidae Schwager, 1877

## Genus Trochammina Parker and Jones, 1859

Trochammina sp.

## Plate 1, Figure 10

Test small, almost as high as broad, finely arenaceous, somewhat conical; chambers subglobular, inflated, increasing rapidly in size; initial end broadly rounded; sutures on the ventral side straight, radial, depressed, indistinct in early portion but later slightly depressed on the dorsal side; 4 to 5 chambers in the final whorl; ventrally umbilicate; aperture small, umbilical and/or areal opening. Length: up to .30 mm.

Remarks: There are some reservations as to the generic assignment of this Claiborne species because of ambiguous position of aperture. Here it is tentatively classified under Trochammina because of its trochospiral test.

## Family Ataxophragmiidae Schwager, 1977

## Genus Tritaxis Reuss, 1860

Tritaxis columbiana (Howe)

## Plate 1, Figure 11

Pseudoclavulina columbiana Howe, 1939, Louisiana Dept. Conserv., Geol. Bull. no. 14, p. 33, pl. 2, figs. 9-10.

Pseudoclavulina elongata Hussey, 1943, Jour. Pal. Vol. 17, no. 2, p. 161, pl. 26, figs. 3-4

Early portion triserial, later uniserial occupying most of the test; circular in cross-section; wall thick and coarsely agglutinated with arenaceous material and minute foraminifera shells; chambers numerous, not labyrinthic;

sutures indistinct except the last one which is broadly depressed; aperture terminal, rather indistinct. Length: up to 1.3 mm. Diameter: up to .57 mm.

Genus *Karrerella* Cushman, 1933

*Karrerella mauricensis* Howe and Ellis

Plate 1, Figure 12

*Karrerella mauricensis* Howe and Ellis, 1939, Louisiana  
Dept. Conserv., Geol. Bull, no. 14, p. 34, pl. 2,  
figs. 1-2.

*Karrerella ovata* Hussey, 1943, Jour. Pal. Vol. 17, no. 2,  
p. 161, pl. 26, figs. 5.

Test elongate, finely arenaceous, tapering very rapidly toward initial end, broader across the last two chambers; periphery broadly rounded; later chambers somewhat inflated, increasing rapidly in size; sutures rather indistinct; aperture areal, produced on a short neck or a rim above the base of the final chamber. Length: up to .45 mm. Width: up to .22 mm.

#### SUBORDER MILIOLINA

Family Fischerinidae Millett, 1898

Genus *Cyclogyra* Wood, 1842

*Cyclogyra lisbonensis* (Bandy)

Plate 1, Figure 13

*Cornuspira lisbonensis* Bandy, 1949, Bull. Amer. Pal. Vol. 32,  
no. 131, pl. 1, p. 17-18, figs. 2 a-b.

Test planispiral, composed of round tube enlarging gradually; periphery rounded; sutures distinct, slightly depressed; aperture oval open end. Diameter: .50 mm.



Family Nubeculariidae Jones, 1875

Genus Spiroloculina d'Orbigny, 1826

Spiroloculina lamposa Hussey

Plate 1, Figure 14

Spiroloculina lamposa Hussey, 1949, Jour. Pal., Vol. 23,  
no. 2, p. 121, pl. 26, fig. 6

Test elliptical in outline, strongly compressed, slightly biconcave; chambers added in a single plane, initial chambers indistinct; aperture terminal, simple, rounded, on a short neck. Length: up to .45 mm. Width: up to .22 mm.

Family Milolidae Ehrenberg, 1839

Genus Quinqueloculina d'Orbigny, 1826

Quinqueloculina sp.

Plate 1, Figure 15

Test almost circular to ovate in side view, subtriangular in transverse section; periphery rounded; smooth, aperture round, not produced, with simple tooth. Length: up to .27 mm. Width: up to .23 mm.

Quinqueloculina claiborniana Standnichenko

Plate 1, Figure 19

Quinqueloculina claiborniana Standnichenko, 1927, Jour. Pal.  
Vol. 1, no. 3, p. 226, pl. 38, figs. 23-24.

Quinqueloculina amigdulata Hussey, 1949, Jour. Pal., Vol. 23,  
no. 2, p. 120, pl. 25, figs. 19-20.

Quinqueloculina acuta Hussey, 1949, Jour. Pal., Vol. 23, no. 2,  
p. 120, pl. 25, figs. 17-18.

Size of test varies. Transverse section bluntly triangular; chamber ventricose; periphery rounded; sutures distinct, unequally curving; final chamber projecting beyond

the base of the penultimate chamber, aperture large, rounded, produced on a short neck with a simple tooth. Length: up to .97 mm. Width: up to .55 mm.

Quinqueloculina danvillensis Howe and Wallace

Plate 1, Figure 16

Quinqueloculina danvillensis Howe and Wallace, 1932,  
Louisiana Dept. Conser., Geol. Bull., no. 2, p. 22,  
pl. 2, figs. 2 a-c.

Test slender, elongated, about 3 times as long as broad; sutures broadly depressed; aperture round with small bifurcated tooth produced on a long neck. Length: up to .56 mm. Width: up to .20 mm.

Quinqueloculina cf. Q. lamarckiana d'Orbigny

Plate 1, Figure 18

Quinqueloculina lamarckiana d'Orbigny, 1839, in De la Sagra,  
Histoire Physique, Folitique et naturelle de lile de  
Cuba, Foraminiferas, p. 189, pl. 11, figs. 14-15.

Quinqueloculina fragilissima Hussey, 1949, Jour. Pal., Vol.  
23, no. 2, p. 121, pl. 25, figs. 16, 21.

Test ovate in side view, sharply triangular in end view; periphery acutely angled but not carinate; sutures distinct, slightly depressed; last chamber slightly extended at the apertural end forming an elliptical neck; aperture round with simple tooth. Length: up to .72 mm. Width: up to .42 mm.

Remarks: Q. lamaerckiana is a recent species. However, this Eocene species resembles so close to the type description and figures of Q. lamarckiana that it is tentatively assigned as Q. lamarckiana. If further examination proves any differences between the two species, Q. fragilissima will

retain its original designation.

Quinqueloculina cf. Q. leonensis Applin and Jordan

Plate 1, Figure 17

Quinqueloculina leonensis Applin and Jordan, 1945, Jour. Pal.  
Vol. 19, no. 1, pl. 18, fig. 9.

Test fusiform, nearly twice as long as broad; periphery rounded; well ornamented with closely spaced papillae throughout the surface; sutures depressed; apertural end extended very shortly; aperture round. Length: up to 1.1 mm. Width: up to .6 mm.

Quinqueloculina yeguaensis Weinzierl and Applin

Plate 2, Figure 1

Quinqueloculina yeguaensis Weinzierl and Applin, 1929, Jour.  
Pal. Vol. 3, p. 393, pl. 44, fig. 4.

Test medium sized for the genus, roughly ovate in outline, somewhat triangular in transverse section; periphery smoothly angled; wall smooth; polished; sutures distinct, curved, depressed; aperture a simple round opening at the end of a short neck with a simple tooth which may be slightly bifid. Length: up to .60 mm. Width: up to .37 mm.

Genus Triloculina d'Orbigny, 1826

Triloculina paulocostata Cushman and Garrett

Plate 2, Figure 2

Triloculina paulocostata Cushman and Garrett, 1934, Contr.  
Cushman Lab. Foram. Res., Vol. 10, p. 19, pl. 9, figs.  
6-7.

Test about twice as long as broad, slightly compressed; periphery broadly rounded; surface strongly ornamented by numerous longitudinal costae; final chamber broadest at

the base, strongly overlapping previous chamber; sutures depressed but obscured by costae; aperture round with a prominent lip. Length: up to .32 mm. Width: up to .17 mm.

Triloculina rotunda d'Orbigny

Plate 2, Figure 3

Triloculina rotunda d'Orbigny, 1826, Ann. Sci. Nat., Vol. 7, p. 299, no. 4

Test small, oval in outline, compressed; surface smooth polished; periphery broadly rounded; sutures rather indistinct but depressed; aperture semicircular opening without a neck or lip. Length: up to .28 mm. Width: up to .20 mm.

Triloculina trigonula (Lamarck)

Plate 2, Figure 4

Miliolites trigonula Lamarck, 1804, Ann. Mus. Vol. 5, p. 351, no. 3, Vol. 9, pl. 17, fig. 4, 1807

Test strongly built, slightly longer than broad, distinctly triangular in transverse section; periphery subacutely rounded; sutures distinct; wall smooth; aperture circular with a bifid tooth. Length: up to .77 mm. Width: up to .6 mm.

SUBORDER ROTALIINA

Family Nodosariidae Ehrenberg, 1838

Genus Nodosaria Lamarck, 1812

Nodosaria latejugata Gumbel

Plate 2, Figure 5

Nodosaria latejugata Gumbel, 1818, K. Bayer. Akad. Wiss. Munchen, Mat.-Physk. Cl., Abh., bd. 10 (1870), abt. 2, p. 619, pl. 1, fig. 32

Test large, straight, stout; chambers are broad as long, globose; sutures broadly depressed; surface ornamented with 10 to 12 high costae continuous across the chambers.

Genus *Dentalinoides* Marie, 1941

? *Dentalinoides resupinata* (Gümbel)

Plate 2, Figure 6

*Nodosaria resupinata* Gümbel, 1868, K. Bayer. Akad. Wiss. München Math.-Physic. Cl., Abh., bd. 10, abt. 2, p. 615, pl. 1, fig. 24.

Test elongated; chambers truncated, fusiform; wall smooth, thin, finely perforate; sutures straight, horizontal, broadly depressed; some initial chambers bulbous with spine; aperture round, central, terminal, with slight rim. Length: up to .7 mm or more.

Genus *Dentalina* Risso, 1826

*Dentalina communis* (d'Orbigny)

Plate 2, Figure 7

*Nodosaria* (*Dentalina*) *communis* d'Orbigny, 1826, Ann. Sci. Nat., Paris, France, ser. 1, tome 7, p. 254, type figure not given.

*Dentalina acinacoides* Hussey, Jour. Pal. vol. 23, no. 2, 1849, p. 126, pl. 26, fig. 29.

Test arcuate, circular in cross section; chambers increasing rapidly in length, 6 to 8 in adult; dorsal side gently lobulate; sutures oblique to the periphery; aperture radiate, terminal at peripheral angle. Length: up to 1.1 mm.

Dentalina cf. D. consobrina d'Orbigny

## Plate 2, Figure 8

Dentalina consobrina d'Orbigny, 1846, Foram. Foss. Bass. Tert., Vienne, p. 46, pl. 2, figs. 1-3.

Test slightly curved; initial chamber somewhat inflated with short spine; sutures oblique to the periphery, broadly depressed; wall thin, hyaline, finely perforate; aperture terminal, radiate at the peripheral angle. Length: up to .43 mm.

Dentalina vertebralis (Batsch) subsp. albatrossi (Cushman)

## Plate 2, Figure 9

Nodosaria vertebralis (Batsch) var. albatrossi Cushman, 1923, U. S. Nat. Mus., Bull., no. 104, p. 87, pl. 15, fig. 1

Nodosaria pyriformis Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 127, pl. 26, fig. 25

Test elongate, slightly curved; initial chamber often greater than penultimate one; chambers numerous; sutures broad, of clear shell material, not depressed except near the apertural end; wall ornamented with numerous sharp longitudinal costae; initial end often with short spine; aperture radiate, terminal. Length: up to 5 mm.

Genus Lagena Walker and Jacob in Kanmacher, 1798

Lagena hispida Reuss

## Plate 2, Figure 10

Lagena hispida Reuss, 1858, Zeitshr. Deutsch. Geol. Gensell., Vol. 10, p. 434.

Test globular; wall finely hispid; aperture rounded, at the end of a long slender neck. Diameter: up to .16 mm.

Lagena cf. L. laevis (Montagu) subsp. stagensis Bandy

Plate 2, Figure 11

Lagena laevis (Montagu) var. stagensis Bandy, 1949, Bull. Amer. Pal., Vol. 32, no. 131, p. 56, pl. 7, fig. 15.

Test ovate in side view, circular in cross-section; wall smooth, finely perforate; aperture round on a short neck; length: up to .28 mm. Diameter: up to .20 mm.

Lagena ouachitaensis Howe and Wallace subsp. alabamensis Bandy

Plate 2, Figure 12

Lagena ouachitaensis Howe and Wallace var. alabamensis Bandy, 1949, Bull. Amer. Pal., Vol. 32, no. 131, p. 57, pl. 7, fig. 12.

Test ovate, tapering toward apertural end, base rounded circular in cross section; wall ornamented with numerous fine longitudinal costae (at least 20 or more); widest below the middle; aperture open end on a relatively long neck with a few ring-like costae. Length: up to .2 mm. Diameter: up to .09 mm.

Lagena striata (d'Orbigny) subsp. strumosa Reuss

Plate 2, Figure 13

Lagena strumosa Reuss, 1858, Zeitschr. Geol. Ges., p. 434; Sitz. Akad. Wiss. Wein., Vol. 46, pt. 1, 1862 (1863), p. 328, pl. 4, fig. 49.

Test globular, slightly ovate in side view, circular in cross-section; wall ornamented with more than 24 fine longitudinal costae; aperture open end on relatively long tubular neck; neck may be ornamented by one or more ring like costae around it. Longer diameter: up to .25 mm.

Lagena sp.

## Plate 2, Figure 14

Test equidimensionally globular; wall smooth, polished; aperture round on a relatively long slender neck. Diameter: up to .19 mm.

Genus Lenticulina Lamarck, 1804

Lenticulina abuillotensis (Bermudez)

## Plate 2, Figure 15

Robulus abuillotensis Bermudez, 1949, Cushman Lab. Foram. Res., Spec. publ. no. 25, p. 119, pl. 8, figs. 1-2.

Test circular in outline, equally biconvex; strongly umbonate, clear shell material occupying a large part of the central area; periphery angled with a narrow keel; 9-12 chambers in the last coil, increasing gradually in size; sutures slightly curved, flush, may be slightly limbate; aperture radiate at peripheral angle with a narrow median slit. Diameter: up to .95 mm.

Lenticulina alatolimbata (Gümbel)

## Plate 2, Figure 16

Robulina alatolimbata Gumbel, 1868, Abhandl. Kon. Bay. Akad. Wiss., Cl. 2, Vol. 10 (1870), p. 641, pl. 2, figs. 70 a-b.

Test relatively small for the genus, almost circular in outline, biconvex, lensoid; periphery sharp to bluntly keeled; wall smooth; 6-7 chambers in the final coil; umbonal area filled with clear shell material; sutures distinct, thick, slightly curved, flush, transparent; aperture radial at the peripheral angle. Diameter: up to .60 mm.



Lenticulina inhabilis (Israelsky)

## Plate 2, Figure 17

Robulus inhabilis Israelsky, 1955, U. S. Geological Survey, prof. paper no. 240-B, p. 61, pl. 17, figs. 23-24.

Test almost circular in outline, strongly biconvex; periphery narrow but sharply keeled, later portion rather bluntly keeled; wall smooth, polished; chambers about 5 in the final whorl, sutures limbate, flush, almost straight, strongly oblique to the periphery and umbo; umbo somewhat eccentric; apertural face V-shaped, concave, distinctly rimmed; aperture radiate with median slit extending downward from the peripheral angle. Diameter: up to .71 mm.

Lenticulina kimituensis (Asano)

## Plate 2, Figure 18

Robulus kimituensis Asano, 1938, Tohoku Imp. Univ. Sci. Repts., ser. 2 (Geol.), Vol. 19, (1937-1938) no. 2, p. 203.

Test large, circular in outline; periphery smoothly angled, not keeled; wall smooth, polished; chamber about 10 in the last whorl; sutures flush, slightly curved; strongly umbonate, umbo filled with clear shell material; aperture radiate at peripheral angle. Diameter: up to 1.7 mm.

Lenticulina laticostata (Tutkovski)

## Plate 2, Figure 19

Cristellaria laticostata Tutkovski, 1888, Soc. Nat. Kieff, Mem., Vol. 9, no. 1-2, p. 36, pl. 5, fig. 2 a-c.

Test equally biconvex; periphery distinctly keeled; chambers 6-7 in the last whorl; wall smooth; sutures thick; strongly limbate, elevated, spirally curving from the center,

oblique to the periphery; apertural fact distinctly rimmed, flat to slightly concave; aperture radiate at the peripheral angle. Diameter: up to .85 mm.

Lenticulina mayi (Cushman and Parker)

Plate 2, Figure 26

Robulus mayi Cushman and Parker, 1931, Cushman Lab. Foram. Res., Contr., Vol. 7, p. 2, pl. 1, figs. 3-5.

Planularia parva Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 125, pl. 26, fig. 5.

Test small, much compressed, later chambers tend to elongate; periphery subacute, slightly keeled; sutures distinct, curved; wall smooth, finely perforate; aperture radiate at the peripheral angle. Length: up to .36 mm.

Lenticulina midwayensis (Plummer)

Plate 2, Figure 20

Cristellaria midwayensis Plummer, 1927, Texas Univ. Bull. 2644, p. 95, pl. 13, fig. 5.

Robulus trochoides Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 124, pl. 25, fig. 11.

Test large, circular in outline; periphery angular and bluntly keeled; chambers about 11 in the final whorl in adult; surface smooth, polished; sutures thickly limbate, elevated, very slightly curved, radiating from large clear central umbo; aperture radiate at the apex of the last chamber. Diameter: up to 1.2 mm.

Lenticulina pseudocultrata (Cole)

Plate 2, Figure 21

Robulus pseudocultratus Cole, Bull. Amer. Pal., 1929, Vol. 14, no. 51, p. 19, pl. 1, fig. 5.

Test circular in outline, somewhat compressed; periphery broadly and sharply keeled with clear shell material; wall smooth, polished; chambers about 7-8 in the final whorl; sutures distinct gently curved, flush, widening as they approach the keel; aperture radiate. Diameter: up to .65 mm.

Lenticulina pseudoligostegia (Martin)

Plate 2, Figure 21

Robulus pseudoligestegius Margin, 1964, Austria Geol. Bundesanst., Jahrb., Sonderb., no. 9, p. 69, pl. 6, figs. 12 a-c.

Test broadly biconvex, with tendency to uncoil; periphery bluntly rounded; chambers about 6 in the final whorl, last chamber somewhat inflated; wall smooth; finely perforate; sutures distinct, flush, slightly curved; aperture radiate at the peripheral angle on a slight protuberance. Length: up to .3 mm.

Lenticulina cf. L. pseudosecans (Cushman) new subsp.

Plate 2, Figure 23

Robulus pseudosecans Cushman, 1938, Contr. Cushman Lab. Foram. Res., Vol. 14, part 2, p. 32, pl. 5, fig. 3.

Test unequally biconvex; strongly umbonate; periphery bluntly keeled; wall smooth; chambers about 9 in the final whorl, increasing gradually in size; sutures strongly limbate, raised, curved, somewhat thickened at the peripheral end, inner end of sutures fused together to form a ring circling the umbonal boss which is separated from this ring by a narrow, circling furrow; aperture radiate at the peripheral angle with a short slit extending downward on the apertural face. Diameter: up to .8 mm.

Remarks: This subspecies differs from Lenticulina pseudosecans only by a depressed circle around the umbo which is a consistent characteristic in this subspecies.

Lenticulina stephensoni (Cushman)

Plate 2, Figure 24

Robulus stephensoni Cushman, 1939, Contr. Cushman Lab. Foram. Res., Vol. 15, pt. 4, p. 90, pl. 16, figs. 2-3.

Robulus navarroensis Cushman, 1939, Cushman Lab. Foram. Res., Vol. 15, pt. 4, p. 90, pl. 16, figs. 2-3.

Test large, circular in outline; strongly biconvex; biumbonate; periphery acute, somewhat bluntly keeled; wall smooth, polished; chambers 9-10 in the final whorl, increasing gradually in size; umbonal area filled with clear shell material; sutures clear, flush, curved; aperture radiate at peripheral angle with a short narrow slit extending downward on the apertural face. Diameter: up to 1.5 mm.

Lenticulina velascoensis White

Plate 2, Figure 25

Lenticulina velascoensis White, 1928, Jour. Pal., Vol. 2, pl. 28, fig. 8 a-b, p. 199

Test flattened, small for the genus, biconvex; lenticular; sharply and broadly carinate with thin, clear shell material; umbonal area filled with clear shell material through which most of previous chambers can be seen; about 9 chambers in the final whorl; sutures clear, flush, curved; aperture radiate, slightly pointed. Diameter: up to .32 mm.

Genus *Marginulina* d'Orbigny, 1826*Marginulina subbullata* Hantken

## Plate 3, Figure 1

*Marginulina subbullata* Hantken, 1875, Hungary, K. Ungar.  
 Geol. Anst., Mitt. Jahrb., bd. 4, heft. 1, p. 46,  
 pl. 4, figs. 9-10.

*Marginulina bulbosa* Hussey, 1949, Jour. Pal., Vol. 23, no. 2,  
 p. 124, pl. 26, figs. 7-8.

Early stage coiled, later uncoiling uniserially,  
 circular in transverse section; chambers bulbous, inflated,  
 rapidly increasing in size; sutures strongly depressed, wall  
 smooth; aperture radiate, pointed at the peripheral angle.  
 Length: up to .4 mm.

*Marginulina* sp.

## Plate 3, Figure 2

Test elongate, circular in cross-section, slightly  
 coiled; chambers inflated; wall smooth, finely perforate;  
 sutures depressed, oblique; aperture radiate, pointed at  
 the peripheral angle. Length: up to .32 mm.

Remarks: This species may have been described but  
 due to insufficient number of specimens, a correct identi-  
 fication is impossible.

Genus *Orthomorphina* Stainforth, 1952*Orthomorphina antillea* (Cushman)

## Plate 3, Figure 3

*Nodosaria antillea* Cushman, 1923, U. S. Nat. Mus., Bull.  
 No. 104, p. 91, pl. 14, fig. 9.

Test straight or slightly arcuate; chambers globular,  
 up to 7 in adult; wall smooth, polished; sutures horizontal,

straight, clear, broadly depressed; aperture round, terminal on a short cylindrical neck with distinct phialine lip.

Length: up to .52 mm.

Remarks: This species is placed on the genus Orthomorphina on the basis of inflated globular chambers and round terminal aperture produced on the short neck. Overall figure of the test somewhat looks more similar to Stilostomella; however, Stilostomella has an indented terminal aperture with internal spatulate tooth.

Orthomorphina camerani (Dervieux)

Plate 3, Figure 4

Nodosaria camerani Dervieux, 1894, Soc. Geol. Ital. Bull., Vol. 12 (1893), fasc. 4, p. 612, pl. 5, figs. 40-41.

Nodosaria selenoides Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 127, pl. 26, fig. 30.

Test elongate, arcuate, tapering into sharp apex; sutures straight, not depressed except last two; chambers increasing gradually in size; aperture radiate; eccentrically produced on a neck. Length: up to 1.2 mm.

Orthomorphina delicata (Hussey)

Plate 3, Figure 5

Nodosaria delicata Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 127, pl. 26, fig. 21.

Test arcuate, ornamented with faint longitudinal costae which tend to develop short spines near the base of each chamber; chambers longer than broad; sutures distinct, broadly depressed, straight to slightly oblique; aperture terminal, radiate at the peripheral angle. Length: up to .8 mm.

Remarks: Holotype of N. delicata has a round terminal aperture instead of terminal radiate aperture.

Genus Pseudonodosaria Boomgart, 1949

Pseudonodosaria conica (Neugeboren)

Plate 3, Figure 6

Glandulina conica Neugeboren, 1850, Sieben. Ver. Naturw. Herrmannstadt, Verh. Mitt., jahrg. 1, no. 4, p. 51, pl. 1, fig. 5 a-b.

Nodosaria primitive Hussey, 1943, Jour. Pal., Vol. 17, no. 2, p. 165, pl. 26, fig. 1.

Test stout, conical with broadly rounded end, circular in cross-section, broadest near the apertural end; chambers few about 4-5, last chamber slightly inflated; sutures distinct in later stage, horizontal, straight, slightly depressed, if at all; wall smooth, polished; aperture radiate, terminal, slightly produced. Length: up to .4 mm. Diameter: up to .22 mm.

Pseudonodosaria elliptica (Reuss)

Plate 3, Figure 7

Glandulina elliptica Reuss, 1863, K. Akad. Wiss., Math.-Naturw. Cl. Sitzber., bd. 48, abt. 1, p. 47, pl. 3, figs. 29-31.

Test elongate, fusiform, circular in transverse section; later chambers enlarging rapidly and strongly overlap previous one; wall smooth, finely perforate; sutures straight, horizontal, flush, the last septum slightly depressed; initial end more rounded; aperture radiate, somewhat pointed. Length: up to .42 mm.

Pseudonodosaria cf. P. ovula (d'Orbigny)

Plate 3, Figure 8

Glandulina ovula d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne. Gide et Comp., p. 29, pl. 1, figs. 6-7.

Test ovate, initial end sharply pointed; chambers enlarging and overlapping strongly, last chamber slightly inflated; wall smooth; sutures indistinct, horizontal in early stage, last sutures slightly to strongly depressed; aperture radiate, terminal, slightly produced on a neck-like extension. Length: up to .37 mm. Diameter: up to .19 mm.

Pseudonodosaria pleniluna (Howe and Wallace)

Plate 3, Figure 9

Lagena pleniluna Howe and Wallace, 1932, Louisiana Dept. Conserv., Geol. Bull. no. 2, p. 29, pl. 6, fig. 5.

Test consists of 2 to 3 chambers in adult, circular in cross-section; chambers globular, initial chamber larger than the succeeding one; wall smooth; sutures straight, horizontal, depressed; aperture terminal, radiate. Length: up to .21 mm. Diameter: up to .14 mm.

Remarks: Holotype of L. pleniluna was originally described on a specimen which has a terminal radiate aperture on a single globular chamber. However, there is no foraminiferal genus established for such a species. Since there are a number of specimens observed from Claiborne samples which possess one or more chambers uniserially arranged but with the same characteristic aperture and shape of chamber, L. pleniluna was amended to include multichambered species.

Genus Saracenaria DeFrance in de Blainville, 1824

Saracenaria limbata Hussey

Plate 3, Figure 10



Saracenaria limbata Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 126, pl. 26, figs. 15, 18.

Saracenaria parva Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 126, pl. 26, fig. 13

Test triangular in transverse section; early coiled portion narrow and bluntly keeled, later keel less prominent; 6 to 7 chambers visible; wall smooth, polished; sutures curved, limbate, flush; apertural face broadly convex, triangular in outline; aperture radiate with elongated slit extending downward. Length: up to .57 mm.

Genus Vaginulina d'Orbigny, 1826

Vaginulina lineara (Carsey)

Plate 3, Figure 11

Cristellaria lineara Carsey, 1926, Texas Univ. Bull., no. 2612, p. 36, pl. 2, fig. 3.

Test elongate, slightly arcuate, gently lobulate on the ventral side of the later portion, slightly compressed; periphery broadly rounded; elliptical in transverse section; wall smooth, finely perforate; chambers broader than long, early portion slightly coiled, later chambers may be somewhat inflated; sutures wide, clear, flush; aperture pointed, radiate at peripheral angle. Length: up to .90 mm. Width: up to .12 mm.

Remarks: This species has been called Vaginulina legumen var. elegans without any apparent reason. There is no resemblance at all between the two species. In some specimens the last one or two chambers tend to be globular with circular cross-section. Specimens with this morphologic characteristic were described as Dentalina colei by Cushman.

Genus *Vaginulinopsis* Silverstri, 1904*Vaginulinopsis hybrida* (Terquem)

## Plate 3, Figure 12

*Cristellaria hybrida* Terquem, 1870, Acad. Imp. Metz. Mem.,  
Metz, France, 1870, annee 50 (ser. 2, annee 17)  
(1868-1869), p. 441, figs. 1-3, 13, 14, 16-19, 24-28, 30

*Marginulina subglobosa* Hussey, 1949, Jour. Pal., Vol. 23,  
no. 2, p. 123, pl. 26, fig. 16.

*Marginulina nonconforma* Hussey, Ibid, p. 122, pl. 26, fig. 9.

*Marginulina inornata* Hussey, Ibid, p. 123, pl. 26, fig. 11, 12.

Test coiled in early stage, later uncoiled, transverse section of later portion triangular; initial chamber globular, chambers broader than high; dorsal periphery bluntly angled, but not carinate; suture distinct, wide, clear, depressed, gently curved; aperture radiate, somewhat pointed at the peripheral angle. Length: up to .45 mm.

Remarks: In the years between 1870 and 1885 Terquem described numerous similar species of *Cristellaria* with hundreds of figures, one of which was *C. hybrida*. There is some doubt about the variety of species designation, because there were 30 figures given as *C. hybrida* in the original description. Figure 30 of those original *C. hybrida* appears to match exactly with *M. subglobosa*. Examined holotypes of *M. subglobosa*, *M. nonconforma*, and *M. inornata* show no differences at all between them.

*Vaginulinopsis mexicanus* (Cushman)

## Plate 3, Figure 13

*Cristellaria mexicana* Cushman, 1925, Bull. Am. Assoc. Petrol. Geol. Vol. 9, no. 2, p. 299, pl. 4, figs. 1-2.

Marginulina anocoides Hussey, 1943, Jour. Pal., Vol. 17, no. 2, p. 161, pl. 25, fig. 3.

Marginulina variata Hussey, Ibid, p. 122, pl. 26, figs. 7-8.

Marginulina insignifica Hussey, Ibid, p. 122, pl. 25, fig. 7.

Marginulina producta Hussey, Ibid, p. 123, pl. 25, fig. 9.

Robulus limbatus Hussey, Ibid, p. 124, pl. 25, fig. 13.

Test biconvex, early portion involute, lenticular, later portion tends to uncoil into arcuate uniserial stage; transverse section of later chambers elliptical; chambers numerous, much broader than high; periphery sharply or bluntly keeled in early stage; sutures raised, strongly limbate, curved, sometimes broken into bead-like knobs in the center of the coiled stage; aperture radiate, slightly produced at peripheral angle. Length: up to 1.35 mm.

Family Polymorphinidae d'Orbigny, 1839

Genus Globulina d'Orbigny in de la Sagra, 1839

Globulina gibba d'Orbigny

Plate 3, Figure 14

Globulina gibba d'Orbigny, 1826, Annales Sci. Nat., Vol. 7, p. 266, no. 10, Modeles no. 63.

Test globular to subglobular, cross-section almost circular; sutures not depressed; wall smooth, finely perforate; aperture radiate, sometimes pointed. Length: up to .4 mm. Diameter: up to .3 mm.

Globulina inaequalis Reuss

Plate 3, Figure 15

Globulina inaequalis Reuss, 1850, K. Akad. Wiss. Wien Denkschr., Vol. 1, p. 377, pl. 48, fig. 9.

Test elongated, ovate, slightly compressed, more rounded at the base; apertural end pointed; sutures indistinct, not depressed; wall smooth, finely perforate; aperture radiate. Length: up to .43 mm. Diameter: up to .27 mm.

Globulina minuta (Roemer)

Plate 3, Figure 17

Polymorphina minuta Roemer, 1838, Neues Jahrb. für Min., p. 386, pl. 3, fig. 35.

Guttulina obscura Hussey, 1949, Jour. Pal. Vol. 23, no. 2, p. 129, pl. 26, fig. 18.

Guttulina magna Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 129, pl. 26, fig. 28.

Test elongated, more or less fusiform, broadest below the middle, both ends pointed; sutures not depressed; wall smooth; aperture radiate, pointed. Length: up to .37 mm. Diameter: up to .22 mm.

Genus Guttulina d'Orbigny in de la Sagra, 1839

Guttulina irregularis (d'Orbigny)

Plate 3, Figure 16

Globulina irregularis d'Orbigny, Foram. Foss. Bass. Tert. Vienne, 1846, p. 226, pl. 13, figs. 9-10.

Test subdeltoidal, equilaterally triangular both longitudinally and transversely; peripheral angles rounded; initial end flat to broadly rounded, apertural end pointed; sutures distinct, slightly depressed; later chambers strongly overlap previous ones, almost reaching to the base; wall smooth; aperture radiate. Length: up to .33 mm.

Guttulina problema d'Orbigny

Plate 3, Figure 18

Polymorphine (Guttulina) problema d'Orbigny, 1826, Annales Sci. Nat., Vol. 7, p. 266, no. 16, Modeles no. 61.

Test roughly fisiform, acute at the apertural end, pointed but rounded at the initial end, broadest below the middle; chambers arranged with increasing distance from the base; sutures distinct, strongly depressed; wall thick, smooth; aperture radiate. Length: up to .55 mm.

Genus Sigmomorphina Cushman and Ozawa, 1928

Sigmomorphina jacksonensis (Cushman)

Plate 3, Figure 19

Polymorphina jacksonensis Cushman, 1926, Contr. Cushman Lab. Foram. Res., Vol. 2, p. 36, pl. 5, figs. 5 a-b.

Test large, broad, compressed; periphery rounded; base of the test rounded, apertural end narrowed, somewhat produced; chambers distinct, sigmoidally arranged; sutures distinct, slightly depressed; wall smooth, polished aperture rounded, radiate. Length: up to .9 mm.

Genus Ramulina Jones in Wright, 1875

Ramulina kittlii Rzehak

Plate 3, Figure 20

Ramulina kittlii Rzehak, 1885, Austria, Geol. Reichsanst., Verh., Wien, p. 187 (Type figure in 1895, Ann naturh. Hofmus. Wien, Bd. 10, pl. 6, figs. 7, 9, 11).

Test composed of one subglobular chamber branching in several directions as a slender tube; wall hyaline, generally smooth except some scattered short spines.

Ramulina mariae (d'Orbigny)

Plate 3, Figure 21

Nodosaria mariae d'Orbigny, 1846, Foraminiferes fossiles du bassin tertiaire de Vienne. Gide et Camp., p. 33, pl. 1, figs. 15-16.

Test consists of elongated bulbous chamber connected by long narrow tube; wall thin, hyaline, finely perforate; aperture simple open end.

Family Glandulinidae Reuss, 1860

Genus Fissulina Reuss, 1850

Fissulina obvia Sequenza

Plate 3, Figure 22

Fissulina (Fissurine) obvia Sequenza, 1862, Dei Terreni Terziarii del distretto di Messina: Part II, p. 60, pl. 2, fig. 1.

Entosolenia vasiiformis Hussey, 1949, Jour. Pal. Vol. 23, no. 2, p. 133, pl. 27, fig. 9.

More or less ovate, compressed; periphery keeled; aperture elliptical slit on the slightly produced end. Length: up to .13 mm.

Fissulina cf. F. orbignyana Sequenza

Plate 3, Figure 23

Fissulina (Fissurine) orbignyana Sequenza, 1862, Dei terreni, Terziarii del distretto di Messina, p. 69, pl. 2, fig. 39.

Test small, oval in outline; periphery thinly carinated which is broader around the neck; wall thin, finely perforate, hyaline; aperture elongated slit produced on long neck. Length: up to .15 mm. Width: up to .10 mm.

Family Turrilinidae Cushman, 1927

Genus Turrilina Andrea, 1884

Turrilina robertsi (Howe and Ellis)

Plate 3, Figure 24

Bulimina robertsi Howe and Ellis, 1939, Louisiana Dept. Conserv., Geol. Bull., no. 14, p. 63, pl. 8, figs. 32, 33,

Test small, somewhat inflated, slightly longer than broad, ovate in side view, circular in cross-section; chambers spirally coiled increasing rapidly in size; wall smooth, finely perforate; sutures distinct, very slightly depressed; aperture low elongated arch at the base of the last chamber. Length: up to .14 mm. Diameter: up to .11 mm.

Family Bolivinitidae Cushman, 1927

Genus Bolivina d'Orbigny, 1839

Bolivina gracilis Cushman and Applin

Plate 4, Figure 1

Bolivina gracilis Cushman and Applin, 1926, Bull. Amer. Assoc. Petro. Geol., Vol. 10, no. 2, p. 167, pl. 7, figs. 1-2.

Test small, very slightly curved; periphery rounded; chambers somewhat inflated; sutures distinct, oblique to the periphery, depressed; wall coarsely perforated, perforations often linearly arranged in lengthwise position; aperture comma-shaped. Length: up to .44 mm. Width: up to .12 mm.

Bolivina louisiana Howe

Plate 4, Figure 2

Bolivina louisiana, Howe, 1939, Louisiana Dept. Conserv., Geol. Bull., No. 14, p. 66, pl. 9, figs. 20-21.

Test small, broad, thickest in the middle, tapering toward the initial end; sloping chambers projecting sharply backward forming strongly serrate periphery; wall smooth, finely perforate; sutures distinct, oblique, slightly depressed; aperture elongated arch at the base of the last

chamber. Length: up to .21 mm. Width: up to .11 mm.

Bolivina cf. B. plicatella Cushman subsp. merra  
Cushman and Ponton

Plate 4, Figure 3

Bolivina plicatella Cushman var. merra Cushman and Ponton,  
1932, Florida Geol. Survey. Bull. 9, p. 82-83, pl. 12,  
fig. 4 a-b.

Test small, short and broad, slightly compressed;  
periphery subacute; sutures curved, oblique and sinuous  
due to retral processes, depressed; aperture comma-shaped,  
extending from the base of the last chamber upward on  
apertural face. Length: .2 mm. Width: .1 mm.

Genus Brizalina Costa, 1856

Brizalina taylori (Howe)

Plate 4, Figure 4

Bolivina taylori Howe, 1939, Louisiana Dept. Conserv., Geol.  
Bull. no. 14, p. 67, pl. 9, figs. 9, 10.

Test compressed, early portion slightly twisted, broadest  
around last two chambers; periphery subacutely rounded; cham-  
bers obliquely arranged with both median and peripheral  
portions extending backward; sutures flush with surface in  
early stage, slightly depressed in later stage; wall finely  
perforate, smooth; aperture elongated comma on the apertural  
face. Length: up to .3 mm. Width: up to .11 mm.

Genus Loxostomoides Reiss, 1957

Loxostomoides nuttalli (Cushman and Siegfus)

Plate 4, Figure 5

Bifarina nuttalli Cushman and Siegfus, 1939, Contro. Cushman  
Lab., Foram. Res., Vol. 15, pt. 2, pg. 28, pl. 6, fig. 6.



Bifarina turriiformis Hussey, 1943, Jour. Pal., Vol. 17, no. 2, p. 166, pl. 26, fig. 2.

Test elongated, early stage slightly compressed, biserial, later half uniserial with circular cross-section; chambers distinct with basal margin crenulating; wall coarsely perforate, early biserial portion ornamented with fine longitudinal costae, later uniserial portion rather smooth; aperture terminal, slightly elliptical with a faint rim. Length: up to 1 mm.

Remarks: This is an unique species which has all the external characteristics of Loxostomoides except for its terminal aperture with a rim. It differs from the typical Loxostomoides by its complete, longer uniserial stage and terminal aperture; however, it is tentatively placed under Loxostomoides.

Family Buliminidae Jones, 1875

Genus Bulimina d'Orbigny, 1826

Bulimina byramensis Cushman and Todd

Plate 4, Figure 6

Bulimina byramensis Cushman and Todd, 1946, Contr. Cushman Lab. Foram. Res., Vol. 22, p. 91, pl. 15, figs. 25, 26.

Test small, initial end subacute, tapering from the greatest width near the aperturan end; triangular in transverse section; the angles rounded; the sides flat or slightly concave; sutures distinct, slightly depressed in later portion; wall distinctly perforate; aperture an elongated loop, extending from the base of the last chamber nearly to the apex of the test. Length: up to .17 mm. Width: up to .10 mm.

Bulimina simplex Terquem

## Plate 4, Figure 7

Bulimina simplex Terquem, 1882, Mem. Soc. Geol. France,  
ser. 3, vol. 2, p. 109, pl. 11 (19), figs. 23 (24 A)

Test small, broadest at the apertural end, tapering;  
chambers slightly inflated; wall smooth, finely perforate;  
sutures distinct, depressed; aperture broad, circular arch,  
occupying most of apertural face. Length: up to .20 mm.  
Diameter: up to .10 mm.

Bulimina truncana Gumbel subsp. aksuatica Morozova

## Plate 4, Figure 8

Bulimina truncana Gumbel Var. aksuatica Morozova, 1939, Soc.  
Nat. Moscow, Bull., Moscow, N. S. vol. 47, (Sect. Geol.,  
vol. 177, no. 4-5, p. 74 (Russian), p. 86 (English) ).

Reussella costata Hussey, 1949, Jour. Pal., Vol. 23, no. 2,  
p. 133, pl. 27, fig. 3.

Test small, triangular in cross section, broadest near  
the apertural end, rapidly tapering near apex to sharp point;  
chambers indistinct; apertural end obliquely truncated;  
peripheral angles rounded; sutures indistinct; surface orna-  
mented with thin, longitudinal costae of up to 18 in number  
except on the last one or two chambers; aperture loop-shaped,  
extending upward from the base of the last chamber. Length:  
up to .20 mm.

Genus Globobulimina Cushman, 1927Globobulimina winniana (Howe)

## Plate 4, Figure 9

Bulimina winniana Howe, 1939, Louisiana Dept. Conserv. Geol.  
Bull., no. 14, p. 64, pl. 8, fig. 31.

Bulimina rotunda Hussey, 1949, Jour. Pal. Vol. 23, no. 2,  
p. 131, pl. 27, fig. 24.

Test ovate, broadest around the middle, both ends tapering; wall smooth, perforate; chambers inflated, elongated, strongly overlapping early chambers; sutures distinct, depressed; aperture comma-shaped at the base of apertural face, with tooth plate attached at one side. Length: up to .40 mm. Width: up to .23 mm.

Remarks: Holotype of B. rotunda Hussey was described as being more tapered at the apertural end and broadest below the middle. But when the holotype and topotypes were examined, there was substantial variation in these morphologic features.

Genus Stainforthia Hofker, 1956

Stainforthia eocaenica (Hussey)

Plate 4, Figure 10

Paleopolymorphina eocaenica Hussey, 1949, Jour. Pal., Vol. 23,  
no. 2, p. 128, pl. 26, fig. 20.

Test elongate, early stage triserial, later twisted biserial, strongly overlapping laterally; chambers slightly inflated, elongate; wall smooth, finely perforate; sutures distinct, depressed, strongly oblique to the periphery; apertural face highly arched and recessed, aperture loop-shaped with incurved lip at one side. Length: up to .39 mm.

Family Uvigerinidae Haeckel, 1894

Genus Uvigerina d'Orbigny, 1826

Uvigerina blancacostata Cole

Plate 4, Figure 11

Uvigerina blancacostata Cole, 1927, Bull. Am. Pal., Vol. 14,  
no. 51, p. 26, pl. 2, fig. 14.

Test almost circular in transverse view; later chambers may be loosely arranged; periphery lobulate; wall ornamented with numerous sharp, discontinuous, longitudinal costae; sutures distinct, deeply depressed, at the base of the chamber the costae tend to break into short spines; aperture round, produced on a prominent cylindrical neck with a phialine lip. Length: up to .37 mm. Diameter: up to .20 mm.

Uvigerina gardnerae Cushman

Plate 4, Figure 12

Uvigerina gardnerae Cushman, 1926, Bull. Am. Assoc. Petro. Geol., Vol. 10, p. 175, pl. 8, figs. 16, 17.

Uvigerina subfusiformis Hussey, 1943, Jour. Pal. Vol. 23, no. 2, p. 132, pl. 27, fig. 1.

Test relatively small, early triserial portion closely arranged, later loosely arranged; periphery lobulate; wall ornamented with numerous low, discontinuous longitudinal costae in early portion; these costae tend to break into spines at the initial end; finely spinose on the last two chambers or so; later chambers somewhat inflated; sutures distinct, deeply depressed on later portion; aperture round, on a slender neck with a faint phialine lip. Length: up to .36 mm. Diameter: up to .16 mm.

Uvigerina cf. U. garzaensis Cushman and Siegfus

Plate 4, Figure 13

Uvigerina garzaensis Cushman and Siegfus, 1939, Contro. Cushman Lab., Foram. Res., Vol. 15, pt. 2, p. 28, pl. 6, fig. 15 a-b.

Test roughly fusiform, early portion tapering, later chamber inflated and loosely arranged, about twice as long as wide; inner face of the last chamber flattened or slightly concave; sutures distinct, much depressed on later portion; wall finely hispid throughout; aperture round, on a short cylindrical neck with a phialine lip. Length: up to .25 mm. Diameter: up to .11 mm.

Genus *Trifarina* Cushman, 1923

*Trifarina vicksburgensis* (Cushman)

Plate 4, Figure 14

*Angulogerina vicksburgensis* Cushman, 1935, Contr. Cushman Lab., Foram. Res., Vol. 11, pt. 2, p. 33, pl. 5, figs. 3, 4.

*Uvigerina subquadrata* Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 131, pl. 27, fig. 12.

Test elongate, about  $2\frac{1}{2}$  times as long as broad, broadest just below the last chamber; periphery rounded; chambers increasing rapidly in size; wall smooth, finely perforate; sutures indistinct in early portion, depressed in later stage; aperture circular on a short neck with prominent lip. Length: up to .52 mm. Width: up to .15 mm.

*Trifarina wilcoxensis* (Cushman and Ponton)

Plate 4, Figure 15

*Pseudouvigerina wilcoxensis* Cushman and Ponton, 1932, Contr. Cushman Lab., Foram. Res., Vol. 8, p. 66, pl. 8, figs. 18 a-b.

Test somewhat elongated in adult, about twice as long as broad, sides in adult nearly flat and parallel; peripheral angle ornamented with narrow, longitudinal, double ridges with deep furrow in between; chambers distinct;

sutures curved and slightly depressed; wall smooth, finely perforate; aperture terminal with a short neck and a narrow lip. Length: up to .35 mm. Width: up to .16 mm.

Trifarina new species

Plate 4, Figure 16

Test small, triangular in cross-section; wall finely but sharply spinose; periphery angled, marked by double longitudinal ridges which are discontinued beyond each chamber; chambers distinct, later portion somewhat inflated; sutures curved, strongly depressed; aperture terminal, produced on a short tubular neck with phialine lip. Length: up to .30 mm. Width: up to .13 mm.

Remarks: This species shows some variation in spinosity and angularity of the periphery. Also, ridges and later chamber arrangement vary very slightly. However, all the major characteristics are consistent in all specimens.

Genus *Sagrina* d'Orbigny in de la Sagra, 1839

Sagrina ellisi (Howe)

Plate 4, Figure 17

Bitubulogerina ellisi Howe, 1939, Louisiana Dept. Conserv., Geol. Bull., no. 14, p. 69, pl. 8, figs. 36-37.

Test very small, triserial to biserial; portion above the angulation of each chamber is smooth and flattened, lower portion spinose; aperture large, terminal with well defined lip; sutures distinct, depressed in biserial stage, indistinct in triserial stage. Length: about .15 mm.

Genus *Siphouvigerina* Parr, 1950

Siphouvigerina elongata (Cole)

Plate 4, Figure 18

Uvigerina elongata Cole, 1927, Bull. Amer. Pal., Vol. 14, no. 51, p. 26, pl. 4, figs. 2-3.

Siphogeneria spinulosa Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 132, pl. 27, fig. 13.

Test elongate, composed of a compact early triserial stage with a tendency to become loosely arranged uniserial; wall hispid; sutures distinct, strongly depressed; aperture terminal on a short neck with narrow phialine lip. Length: up to .40 mm.

Family Discorbidae Ehrenberg, 1838

Genus Discorbis Lamarck, 1804

Discorbis stenzeli Garrett

Plate 4, Figure 19

Discorbis stenzeli Garrett, 1942, Jour. Pal., Vol. 16, no. 4, p. 484, (112) text figs. 1 a-c.

Test heavily constructed, almost equally biconvex; periphery subacutely rounded, very slightly lobulate in later portion; ventral side deeply umbilicate; chambers about 8 in the final whorl; sutures strongly limbate on both sides, elevated; dorsal side more perforate, ventral side almost glassy, non-perforate; aperture low interiormarginal arch. Diameter: up to .48 mm.

Discorbis tallahattensis Bandy

Plate 4, Figure 20

Discorbis tallahattensis Bandy, 1949, Bull. Amer. Pal., Vol. 32, no. 131, p. 27, pl. 16, figs. 7 a-c.

Test small, circular to oval in outline, biconvex; dorsal side usually higher, ventral side convex but deeply umbilicate; periphery angled gently, lobulate, narrowly

carinate; chambers 7-8 in the final whorl, increasing rapidly in size; inner portion of last few chambers tend to develop flaps over the umbilicus; wall smooth, perforate; sutures curved, limbate, slightly depressed on the later portion of the ventral side; more strongly limbate, obliquely curved on the dorsal side; aperture at the base of the last chamber, extending from near the periphery into the umbilicus.

Diameter: up to .35 mm.

Discorbis yeguaensis Weinzierl and Applin

Plate 4, Figure 21

Discorbis yeguaensis Wienzierl and Applin, 1929, Jour. Pal., Vol. 3, no. 4, p. 405, pl. 44, figs. 5 a-c.

Discorbis petalana Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 135, pl. 27, figs. 20-21.

Test roughly oval in outline, compressed, unequally biconvex, more convex on dorsal side; periphery slightly lobulate, thinly carinate; 7-8 chambers on the last whorl, increasing very rapidly in size; sutures curved, depressed, limbate; wall coarsely perforate, hyaline; umbilical area depressed, covered by thin transparent projections extending over the area from the base of the last chamber; aperture elongated interiormarginal opening at the base of the last chamber on the ventral side extending to near the umbilical region. Diameter: up to .43 mm.

Genus Epistominella Husezima and Maruhasi, 1944

Epistominella huneri (Howe)

Plate 4, Figure 22



Pulvinulinella huneri Howe, 1939, Louisiana Dept. Conserv., Geol. Bull., no. 14, p. 81, pl. 11, figs. 14-16.

Siphonina carinata Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 166, pl. 26, fig. 14-15.

Test small, subcircular in outline, biconvex, lensoid; periphery sharply carinate with thin, broad, sometimes serrate, clear shell material; sutures straight, oblique to the periphery, distinctively raised on the dorsal side forming reticulate network especially on the central portion; radial, slightly depressed on the outer portion of the ventral side, centrally raised sharply, giving pitted look at the center; chambers 5-6 in the final whorl; wall perforate; aperture elongated opening on the ventral side, parallel to the periphery, with denticulate inner rim. Diameter: up to .30 mm.

Remarks: In the original description of the holotype, the ventral sutures were incomplete due to poor preservation.

Family Siphoninidae Cushman, 1927

Genus Siphonina Reuss, 1850

Siphonina claibornensis Cushman

Plate 4, Figure 23

Siphonina claibornensis Cushman, 1927, Proc. U. S. Nat. Mus., Vol. 72, art. 20, p. 4, pl. 3, figs. 5 a-c.

Test almost circular in outline, compressed but equally biconvex; periphery slightly lobulate, acute with sharp, serrate, narrow keel; 5 chambers in the final whorl; sutures distinct, depressed, radial, slightly curved on the ventral side, strongly oblique and somewhat limbate on the dorsal side; umbilical regions filled with clear shell material;

wall coarsely perforate; aperture peripheral, elongate, elliptical occupying entire height of the last chamber, with distinct lip, no prominent neck. Diameter: up to .28 mm.

Siphonina danvillensis Howe and Wallace

Plate 4, Figure 24

Siphonina danvillensis Howe and Wallace, 1932, Louisiana Dept. Conserv., Geol. Bull., no. 2, p. 70, pl. 13, fig. 1.

Test nearly circular in outline, almost equally biconvex; periphery acute with sharp, often serrate keel, gently lobulate; 5 chambers on the final whorl, inflated in later portion; ventral sutures radial, depressed, almost straight, dorsal sutures strongly oblique, slightly depressed in later portion; wall smooth, coarsely perforate; aperture peripheral occupying entire height of the last chamber, produced on a short neck with a distinct lip. Diameter: up to .32 mm.

Genus Siphonides Feray, 1941

Siphonides biserialis Feray

Plate 4, Figure 25

Siphonides biserialis Feray, 1941, Jour. Pal., Vol. 15, no. 1, p. 175, figs. 1-4.

Test very small, compressed, dorso-ventrally arcuate, early stage like Siphonina, later biserial; periphery lobate, acutely angled; wall smooth; clear; sutures curved, depressed; aperture elliptical opening, with a phialine lip, produced on a very stout neck positioned eccentrically and obliquely toward the periphery. Length: up to .23 mm. Width: up to .09 mm.

Genus *Siphoninella* Cushman, 1927*Siphoninella chambersi* Howe and Roberts

## Plate 4, Figure 26

*Siphoninella chambersi* Howe and Roberts, 1939, Louisiana  
Dept. Conserv., Geol. Bull. no. 14, p. 77, pl. 10,  
figs. 7-9.

Test unequally biconvex; dorsal side more strongly convex; periphery narrow but sharply keeled, serrate; chambers about 6 in the final whorl, only one in the uncoiled stage; wall smooth, coarsely punctuate; sutures limbate, indistinct, slightly raised on the dorsal side, almost straight, radial, depressed on the ventral side; aperture terminal, elliptical with a distinct phialine lip. Length: up to .33 mm.  
Diameter of coiled portion: up to .22 mm.

*Siphoninella parva* Hussey

## Plate 4, Figure 27

*Siphoninella parva* Hussey, 1949, Jour. Pal., Vol. 23, no. 2,  
p. 138, pl. 29, fig. 1.

Test elongated, small, compressed, trochoid early stage, uniserial stage forms more than  $4/5$  of the entire test; about 5 chambers in the uncoiled stage, spinose at the base of each chamber; sutures in early spiral portion indistinct, deeply depressed in uniserial stage; aperture terminal, elliptical on a short neck with a heavy lip. Length: up to .48 mm.

## Family Asterigerinidae d'Orbigny, 1939

Genus *Asterigerina* d'Orbigny in de la Sagra, 1839*Asterigerina texana* (Stadnichenko)

## Plate 5, Figure 4

Eponides texana Stadnichenko, 1927, Jour. Pal., Vol. 1  
p. 232, pl. 38, figs. 1-5.

Test unequally biconvex, ventrally more convex; periphery sharply keeled with thin, broad, serrate, transparent shell material; 9-10 chambers in the final whorl; chambers on the dorsal side crescentic, supplementary chambers on the ventral side occupying inner half of the primary chambers; surface smooth, perforate except initial one-third of the last whorl on the ventral side which is ornamented by numerous small tubercles; sutures oblique on the dorsal side, sinus on ventral side due to addition of sutures of supplementary chambers; biumbonate with clear shell material; aperture elongated, low, interiomarginal arch on the ventral side. Diameter: up to .9 mm.

Genus *Asterigerinata* Bermudez, 1949

*Asterigerinata*, new species

Plate 5, Figure 5

Test small, planoconvex to concave-convex, dorsal side evenly convex; almost circular in outline, slightly lobulate periphery narrowly carinated; chambers strongly crescentic, 5 chambers in the final whorl; central half of the ventral side occupied by equal number of irregularly rounded, stallate-shaped, supplementary chambers; dorsal surface smooth, ventral side often covered by minute granules; sutures distinct, curved and oblique to the periphery on the dorsal side, radial, curved, slightly depressed on the ventral side, aperture elliptical, distinctly rimmed, located at the anterior base of the last chamber. Diameter: up to .4 mm.

Family Elphidiidae Galloway, 1933

Genus Elphidium de Montfort, 1808

Elphidium, new species

Plate 4, Figure 28

Test circular in outline, rather compressed; periphery slightly lobulate, rounded; chambers about 8 to 10 in the final whorl; wall smooth, finely perforate, polished; sutures gently curved, slightly depressed, with distinct retral process; very spinose in the area below the base of the last chamber; umbilical area often filled with clear shell material; aperture rather obscure, consisting of a series of pores at the base of the last chamber. Diameter: up to .45 mm.

Family Heterohelcidae Cushman, 1927

Genus Chiloguembelina Loeblich and Tappan, 1956

Chiloguembelina crinita (Glaessner)

Plate 5, Figure 1

Gumbelina crinita Glaessner, 1937, Probl. Paleontol., Moscow Univ. Lab. Paleontol., vol. 2-3, p. 383, pl. 4, figs. 34 a-b.

Gumbelina multicellularis Hussey, Jour. Pal., Vol. 23, no. 2, 1949, p. 130, pl. 27, fig. 10,

Test small, slightly twisted, especially in early stage, biserial throughout, broadest around the last two chambers, tapering very rapidly; chambers globose, rapidly enlarging, inflated; sutures distinct, depressed; wall finely perforate, fragile; aperture asymmetrically located arch toward the flat side of the test with narrow hood-like extension over it. Length: up to .25 mm. Width: up to .9 mm.

Genus *Guembelitria* Cushman, 1933*Guembelitria columbiana* Howe

## Plate 5, Figure 2

*Guembelitria columbiana* Howe, 1939, La. Dept. Conserv., Geol. Bull., no. 14, p. 62, pl. 8, figs. 12-13.

Test small, chambers globose and inflated in later portion; sutures distinct, depressed, wall perforate, smooth, aperture small, semicircular arch at the base of the last chamber. Length: up to .16 mm.

## Family Hantkeninidae Cushman, 1927

Genus *Pseudohastigerina* Banner and Blow, 1959*Pseudohastigerina micra* (Cole)

## Plate 5, Figure 3

*Nonion micrus* Cole, 1927, Bull. Am. Paleon., Vol. 14, no. 51, p. 22, pl. 5, fig. 12.

Test partially evolute; chambers globular, inflated, increasing rapidly in size; periphery rounded, strongly lobulate; sutures distinct, depressed, slightly curved; wall thin, smooth, finely perforate; aperture equatorial arch with distinct lip. Diameter: up to .26 mm.

## Family Globorotaliidae Cushman, 1927

Genus *Globorotalia* Cushman, 1927*Globorotalia aequa* Cushman and Renz

## Plate 5, Figure 6

*Globorotalia crassata* (Cushman) subsp. *aequa* Cushman and Renz, 1942, Contr. Cushman Lab., Foram. Res., Vol. 18, pt. 1, p. 12, pl. 3, figs. 3 a-c.

Test small, compressed, almost plano-convex with ventral side more convex; wall hispid except on the last chamber

which tends to be smooth; periphery lobulate, acutely angled but not carinate; chambers about 4-5 in the final whorl, increasing rapidly in size; sutures curved and depressed on the dorsal side, depressed and radial on the ventral side; aperture interiomarginal arch extending into open umbilicus. Diameter: up to .30 mm.

Globorotalia compressa (Plummer)

Plate 5, Figure 7

Globigerina compressa Plummer, 1927, Univ. Texas. Bull. 2644, p. 135, pl. 8, figs. 11 a-c.

Globorotalia perforataminuta Hussey, 1949, Jour. Pal. Vol. 23, no. 2, p. 141, pl. 29, figs. 6-7,

Test small, almost circular in outline, very much compressed; periphery acutely rounded, gently lobulate; wall smooth, finely perforate; chambers about 5 in the final whorl, increasing rather rapidly in size, slightly inflated; sutures curved, depressed; umbilicate; aperture elongated, interiomarginal arch with narrow but distinct flap extending onto the umbilicus. Diameter: up to .19 mm.

Genus Turborotalia Cushman and Bermudez, 1949

Turborotalia bullbrooki (Bolli)

Plate 5, Figure 8

Globorotalia bullbrooki Bolli, 1957, U. S. Nat. Mus. Bull. 215, (135), p. 167-168, pl. 38, figs. 4a-5c.

Test nearly plano-convex, ventrally strongly convex; wall very hispid; chambers peripherally compressed; periphery angled but not carinate, lobulate; chambers 4 in the last whorl increasing rapidly in size; umbilicate; sutures depressed, slightly curved on the dorsal side, straight and

radial on the ventral side; aperture interiomarginal, extra-umbilical arch. Diameter: up to .41 mm.

Turborotalia centralis (Cushman and Bermudez)

Plate 5, Figure 9

Globorotalia centralis Cushman and Bermudez, 1937, Contr. Cushman Lab., Foram. Res., Vol. 13, pt. 1, p. 26, pl. 2, figs. 62-65.

Globorotalia inflata Hussey, 1949, Jour. Pal., Vol. 23, no. 2, 1949, p. 141, pl. 29, fig. 4-5.

Test almost plano-convex, periphery rounded, lobulate; wall distinctly pitted, some may be spinose on the early portion and around the umbilical region; sutures depressed, straight, radial on the ventral side, slightly curved on the spiral side; aperture large, extraumbilical-umbilical arch bordered by a distinct rim. Diameter: up to .37 mm.

Turborotalia mckannai (White)

Plate 5, Figure 10

Globigerina mckannai White, 1929, Jour. Pal., Vol. 2, no. 3, p. 134, pl. 27, figs. 16 a-c.

Test almost circular in outline; wall distinctly hispid, more so on the umbilical region; chambers 5-6 in the final whorl, closely coiled, somewhat compressed peripherally; ventrally more convex; deeply umbilicate; sutures depressed; curved on the dorsal side, straight and radial on the ventral side; aperture relatively large, extraumbilical-umbilical arch often faintly rimmed. Diameter: up to .30 mm.

Turborotalia tribulosa Loeblich and Tappan

Plate 5, Figure 11



Globorotalia tribulosa Loeblich and Tappan, 1957, U. S. Nat. Mus. Bull. 215, p. 185, pl. 56, fig. 3 a-c; pl. 61, figs. 7 a-c.

Test unequally biconvex, ventrally more convex; wall relatively coarsely hispid; periphery lobulate, broadly rounded; chambers subspherical, about 4 in the final whorl, sutures slightly curved, depressed on the spiral side, deeply depressed and straight, radial on the ventral side; aperture interiomarginal, extraumbilical-umbilical arch. Diameter: up to .32 mm.

Family Globigerinidae Carpenter, Parker and Jones, 1862

Genus Globigerina d'Orbigny, 1826

Globigerina gravelli Bronnimann

Plate 5, Figure 12

Globigerina gravelli Bronnimann, 1852, Bull. Amer. Pal., Vol. 34, no. 143, p. 12-13, pl. 1, figs. 16-18.

Test relatively large, low trochospiral; periphery slightly lobulate; wall finely hispid; chambers 5 to 6 in the final whorl, subglobular, flattened peripherally; sutures curved, depressed on the spiral side, almost straight and radial on the ventral side; umbilicus deep, subcircular, aperture large arch, opens into the umbilicus with faint rim, apertural face smooth. Diameter: up to .37 mm.

Globigerina officialis Subbotina

Plate 5, Figure 13

Globigerina officialis Subbotina, 1953, Fossil Foraminifera of the USSR, Trudy, n. s., Bypusk 76, p. 78, pl. 11, figs. 1-7.

Test relatively small, high trochospiral; equatorial periphery strongly lobulate; wall pitted to finely hispid; chambers inflated, spherical 4 in the last whorl, increasing rapidly in size; dorsal side is more convex; sutures deeply depressed, usually not curved, aperture medium high, umbilical arch with faint lip. Diameter: up to .30 mm.

Globigerina cf. G. officalis Subbotina

Plate 5, Figure 14

This species differs from the typical one only by slightly higher trochospiral dorsal side and larger, arched aperture.

Genus Subbotina Brotzen and Pozaryska, 1961

Subbotina boweri (Bolli)

Plate 5, Figure 15

Globigerina boweri Bolli, 1957, U. S. Nat. Mus. Bull. 215, 134, p. 103, pl. 36, figs. 1a-2b.

Test low trochospiral; equatorial periphery lobate; chambers globular, increasing rapidly in size, last chamber much inflated, early ones somewhat compressed, only 3 or 3½ chambers visible on the umbilical side; wall perforate pitted; sutures depressed, slightly curved on the dorsal side, almost straight, radial on the umbilical side; aperture relatively high, umbilical-extraumbilical arch bordered by a narrow, upper rim. Diameter: up to .35 mm.

Family Eponididae Hofker, 1951

Genus Neoeponides Reiss, 1910

Neoeponides mexicanus (Cushman)

Plate 5, Figure 16

Pulvinulina mexicana Cushman, 1925, Bull. Amer. Assoc.  
Petrol. Geol. Vol. 9, no. 2, p. 300, pl. 7, figs. 7-8

Eponides simplex Hussey, 1949, Jour. Pal., Vol. 23, no. 2,  
p. 137, pl. 28, figs. 17, 18.

Test unequally biconvex, dorsally more convex; periphery subacute, bluntly carinate; wall smooth, perforate; chambers 8-11 in the final whorl; sutures distinct, ventral sutures straight to slightly curved, limbate, thicken toward the center where they fuse to form an elevated rim circling the umbilicus, dorsal sutures less limbate, curved; aperture interiomarginal, extending into the umbilicus. Diameter: up to .7 mm.

Family Cibicididae Cushman, 1927

Genus Cibicidina Bandy, 1949

Cibicidina mauricensis (Howe and Roberts)

Plate 5, Figure 17

Cibicides mauricensis Howe and Roberts, 1939, Louisiana Dept.  
Conserv., Geol. Bull., no. 14, p. 87, pl. 13, figs. 4-5.

Test plano convex, spiral side almost involute and slightly concave, ventral side evenly convex; periphery acute, sometimes faintly carinate in early portion; chambers about 10 in the last formed coil, increasing gradually in size; central area on both sides filled with clear shell material; sutures distinct, curved, flush with surface; wall finely perforate, smooth; aperture peripheral, extending on the dorsal side along the base of last 2 or 3 chambers. Diameter: up to .28 mm.

Cibicidina mississippiensis (Cushman)

Plate 5, Figure 18

Anomalina mississippiensis Cushman, 1922, U. S. Geol. Survey, Prof. Paper 129-E, p. 98, pl. 21, figs. 6-8.

Test planoconvex, almost involute, strongly convex on ventral side, dorsal side slightly concave; periphery slightly lobulate, bluntly rounded; chambers about 7 in the final whorl, rapidly increasing in size; last chamber inflated and elevated higher than the other chambers; wall smooth, finely perforate; sutures curved, broad and flush on the dorsal side, depressed on later portion of the ventral side due to inflation of chambers; aperture peripheral, extending along the base of the last two chambers or so on the dorsal side where narrow chamber flaps may extend over the opening. Diameter: up to .27 mm.

Cibicidina hypoconoides (Hussey)

Plate 5, Figure 19

Cibicides hypoconoides Hussey, 1943, Jour. Pal., Vol. 17, no. 2, p. 107, pl. 26, fig. 6-8.

Test high planoconvex, even slightly concavoconvex; periphery angled, almost circular in outline; chambers about 8 in the final whorl; wall smooth, finely perforate; sutures radially curved on the ventral side, somewhat sinuous on the dorsal side; aperture peripheral, extending onto the ventral side at the base of the last few chambers where it is obscured by narrow chamber flaps. Diameter: up to .37 mm.

Genus Cibicides de Montfort, 1808

Cibicides delicatus LeRoy

Plate 5, Figure 20

Cibicides delicatus, LeRoy, 1944, Colorado School of Mines,  
Quart. Vol. 39, no. 3, p. 42, pl. 2, figs. 18-21.

Cibicides glabratus, Hussey, Jour. Pal. Vol. 23, no. 2,  
1949, p. 142, pl. 29, figs. 10, 11.

Test somewhat circular in outline, strongly planoconvex, ventrally convex, even slightly concave on the dorsal side; periphery sharply angled, faintly carinate; wall finely perforate, polished; chambers about 7 in the final whorl; sutures distinct, gently curved, radial and depressed on the ventral side, faintly limbate, curved on the dorsal side; aperture peripheral, extending onto the dorsal side along the base of last one or two chambers. Diameter: up to .28 mm.

Cibicides jeffersonensis Garrett

Plate 5, Figure 21

Cibicides jeffersonensis Garrett, 1929, Jour. Pal. Vol. 13,  
p. 579, pl. 66, fig. 10 a-c.

Cibicides rhsmithi Hussey, 1949, Jour. Pal., Vol. 23, no. 2,  
p. 142, pl. 29, figs. 18-19.

Test small, unequally biconvex, ventrally more convex, nearly circular in outline; periphery subacute; wall coarsely perforate; chambers about 9 in the final whorl; sutures slightly curved, strongly limbate; aperture low, peripheral arch extending a short distance onto the dorsal side. Diameter: up to .45 mm.

Cibicides lawi Howe

Plate 5, Figure 22

Cibicides lawi Howe, 1939, Louisiana Dept. Conserv., Geol.  
Bull. no. 14, p. 87, pl. 13, figs. 12-14.

Test circular in outline; almost equally biconvex; periphery subacute; wall smooth, finely perforate; about

9 chambers in the final whorl; sutures distinct, slightly depressed and curved on the ventral side, oblique on the dorsal side; aperture peripheral with slight lip. Diameter: up to .28 mm.

Cibicides lucidus (Reuss)

Plate 5, Figure 23

Truncatalina lucida Reuss, 1866, K. Akad. Wiss. Wien, Math-Naturw. Cl., Denkschr., bd. 25, abt. 1, p. 160, pl. 4, fig. 15.

Test small, plano-convex to unequally biconvex, ventrally more convex; periphery lobulate, subcarinate; wall rather coarsely perforate; chambers about 8-9 in the last whorl; sutures curved, depressed on the ventral side, indistinct, limbate, oblique on the dorsal side; aperture a small, peripheral arch with a lip extending on to the spiralside along the base of last 2 or 3 chambers. Diameter: up to .30 mm.

Cibicides mammiformis Hussey

Plate 5, Figure 24

Cibicides mammiformis Hussey, 1949, Jour. Pal., Vol. 23, no. 2, pl. 29, p. 142, figs. 16, 17.

Cibicides submammiformis Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 143, pl. 29, figs. 20, 21.

Test planoconvex, almost circular in outline; periphery acutely carinate, slightly lobulate; ventral side evenly convex with distinct umbonal boss; chambers about 8-9 in the last whorl; wall coarsely perforate; sutures slightly curved, rather indistinct and slightly depressed on the ventral side, dorsal sutures distinct, limbate, curved, slightly depressed in later portion, often fused into clear shell

material at the center; aperture small, peripheral arch with faintly developed lip extending into the dorsal side along the base of the last two or three chambers. Diameter: up to .6 mm.

Cibicides cf. C. mimulus Bandy

Plate 6, Figure 1

Cibicides mimulus Bandy, 1949, Bull. Amer. Pal., Vol. 32, no. 131, p. 106, pl. 19, fig. 1.

Test planoconvex to biconvex, ventral side more convex; periphery subacute, slightly lobulate; wall smooth; perforate; chambers about 8 in the final whorl; umblicate on the ventral side; sutures slightly curved, radial, depressed on the ventral side, curved, oblique, limbate on the dorsal side; aperture small, peripheral arch extending a very short distance onto the dorsal side. Diameter: up to .32 mm.

Cibicides cf. C. pseudowuellerstorfi Cole

Plate 6, Figure 2

Cibicides pseudowuellerstorfi Cole, 1927, Bull. Amer. Pal. Vol. 14, no. 51, p. 36, pl. 1, figs. 13, 14.

Test unequally biconvex to planoconvex, generally dorsal side is flat, nearly circular in outline; periphery subacute to slightly carinate; chambers 9-10 in the final whorl; wall smooth, coarsely perforate; sutures distinct, slightly limbate, curved; relatively high umbo on the ventral side; aperture peripheral, extending a short distance onto the dorsal side. Diameter: up to .36 mm.

Remarks: This species shows great variety in size and convexity. Generally small.

"Cibicides" new sp.

## Plate 6, Figure 3

Test unequally biconvex, dorsal side more strongly convex, nearly circular in outline; periphery bluntly angled; wall smooth, coarsely perforate on the dorsal side; chambers about 9 to 10 in the final whorl, gradually increasing in size; sutures distinct, oblique, curved and limbate on the dorsal side, almost straight to very slightly curved, radial, flush on the ventral side; last chamber tends to inflate slightly above the plane of coiling; slightly umbilicate; median portion of the apertural peripheral with narrow but distinct lip, extending a short distance on both sides. Diameter: up to .33 mm.

Family Discocyclinidae Galloway, 1928

Genus Discocyclina Gumbel, 1870

Discocyclina advena (Cushman)

## Plate 6, Figure 4

Orthophragmina advena Cushman, 1921, U. S. Geol. Survey, Prof. paper 128, p. 139, pl. 22, figs. 1-5.

Test very large, very flat, disc-shaped. Diameter: up to 8 mm.

Family Caucasinidae N. K. Bykova, 1959

Genus Fursenkoina Loeblich and Tappan, 1961

Fursenkoina mcguirti (Howe and Roberts)

## Plate 6, Figure 5

Virgulina mcguirti Howe and Roberts, 1939, Louisiana Dept. Conserv. Geol. Bull. no. 14, p. 65, pl. 9, fig. 1.



Virgulina spinulosa Hussey, 1949, Jour. Pal., Vol. 25, no. 2, p. 134, pl. 27, fig. 8.

Test elongate, compressed; chambers sloping backward strongly ending in spinose projections at the periphery; early portion slightly twisted; wall smooth; sutures strongly oblique, depressed; aperture elongate loop on the apertural face. Length: up to .32 mm.

Fursenkoina zetina (Cole)

Plate 6, Figure 6

Virgulina mexicana Cole, (not Cushman), 1927, Bull. Amer. Pal. Vol. 14, no. 51, p. 25, pl. 5, fig. 14 (corrected to *V. zetina* in errata)

Virgulina regularis Hussey, 1949, Jour. Pal. Vol. 23, no. 2, p. 134, pl. 27, fig. 11.

Test small, about  $3\frac{1}{2}$  times as long as broad, axis of early portion twisted, biserial throughout; sutures distinct, slightly depressed, oblique to the periphery; wall smooth, finely perforate; aperture comma-shaped at the base of the last chamber extending upward. Length: up to .4 mm. Width: up to .11 mm.

Family Cassidulinidae d'Orbigny, 1839

Genus Globocassidulina voloshinova, 1960

Globocassidulina globosa (Hantken)

Plate 6, Figure 7

Cassidulina globosa Hantken, 1875, Hungary, K. Ungar. Geol. Anst., Mitt. Jahrb., bd. 4, heft 1, p. 64.

Cassidulina inconspicua Hussey, 1949, Jour. Pal. Vol. 23, no. 2, p. 140, pl. 28, figs. 4, 5.

Test small, subglobose; periphery broadly rounded; about 4 pairs of chambers visible; sutures slightly curved, slightly

depressed; aperture loop-shaped on the apertural face, parallel to the direction of coiling. Diameter: about .12 mm.

Globocassidulina lomitensis (Galloway and Wissler)  
subsp. mexicana (Cole)

Plate 6, Figure 8

Cassidulina lomitensis Galloway and Wissler var. mexicana  
Cole, 1927, Bull. Amer. Pal. Vol. 14, no. 51, p. 32,  
pl. 5, figs. 4, 5.

Test small, subcircular in outline, biserially enrolled, gently flattened; periphery broadly rounded; chambers not inflated, about 4-5 pairs visible ventrally; wall smooth; finely perforate; sutures slightly depressed; aperture loop-shaped, parallel to the plane of coiling. Diameter: up to .14 mm.

Family Nonionidae Schultz, 1854

Genus Nonionellina voloshinova, 1958

Nonionellina winniana (Howe)

Plate 6, Figure 9

Nonionella winniana Howe, 1939, Louisiana Dept. Conserv.  
Geol. Bull. no. 14, p. 60, pl. 7, figs. 26-27.

Test generally ovate, longer than broad; periphery broadly rounded; dorsal side evolute, ventral side involute; chambers 8-9 in the last formed whorl, increasing rather rapidly in size; umbilicate, umbilical region on the ventral side filled with granular material, slightly so on the dorsal side; sutures distinct, gently curved, depressed; aperture equatorial arch extending into the ventral side along the base of the last two chambers. Length: up to .30 mm.

Genus *Nonionella* Cushman, 1926*Nonionella* cf. *N. jacksonensis* subsp. *spiralis* Bandy

Plate 6, Figure 10

*Nonionella jacksonensis* var. *spiralis* Bandy, 1949, Bull. Amer. Pal. Vol. 32, no. 131, p. 77, pl. 11, figs. 7 a-b.

Test small, ovate in outline, ventrally umbilicate, longer than broad, ventral side involute; periphery rounded; last chamber almost reaching over the umbilical region; about 6 chambers in the final whorl, becoming increasingly elongate; sutures rather indistinct, slightly depressed on later partition; wall smooth; finely perforate; aperture peripheral slit extending a short distance into the umbilicus at the base of the last chamber. Length: up to .23 mm.

## Family Alabaminidae Hofker, 1951

Genus *Alabamina* Toulmin, 1941*Alabamina wilcoxensis* Toulmin

Plate 6, Figure 11

*Alabamina wilcoxensis* Toulmin, 1941, Jour. Pal. Vol. 15, no. 6, p. 603, pl. 81, figs. 10-14.*Pulvinulinella bella* Hussey, 1949, Jour. Pal., Vol. 23, no. 2, p. 140, pl. 28, fig. 1-3.

Test low trochospiral, subcircular in outline, unequally biconvex with ventral side being more convex; periphery bluntly acute; usually 6 chambers visible on the final whorl; wall smooth, finely perforate; sutures straight, radial, flush on the ventral side, strongly oblique to the periphery on the dorsal side; aperture narrow, interiomarginal slit hooded by extension of folded wall of the last chamber. Diameter: up to .40 mm.

Family Osangulariidae Loeblich and Tappan, 1964

Genus Gyroidinoides Brotzen, 1942

Gyroidinoides octocameratus (Cushman and Hanna)

Plate 6, Figure 12

Gyroidina soldanii var. octocamerata Cushman and Hanna, 1927,  
Calif. Acad. Sci., Proc. ser. 4, Vol. 16, no. 8, p. 136,  
pl. 14, figs. 16-18.

Gyroidina limbata Hussey, 1949, Jour. Pal., Vol. 23, no. 2,  
p. 136, pl. 28, figs. 6-7.

Test nearly planoconvex, ventrally strongly convex,  
periphery rounded; about 8 chambers in the final whorl;  
umbilicate; sutures straight, radial, slightly depressed,  
sometimes limbate on the ventral side, curved and may be  
limbate on the dorsal side; wall polished, finely perforate;  
aperture interiomarginal slit extending into umbilicus where  
it is covered by the umbilical flap extending from the base  
of the last chamber. Diameter: up to .38 mm.

Family Anomalinidae Cushman, 1927

Genus Anomalinoides Brotzen, 1942

Anomalinoides ammonoides (Reuss)

Plate 6, Figure 13

Rosaline ammonoides Reuss, 1844, Geognostische Skizzen aus  
Böhmen, band 2, p. 214, type fig. not given.

Test weakly biconvex, circular in outline, biumbilicate;  
partially involute; 11-12 chambers in the final whorl; peri-  
phery smoothly rounded; sutures flush; slightly depressed;  
wall perforate, more coarsely so on the ventral side;  
aperture peripheral, extending on to the ventral side along  
the base of the last few chambers, with faint lip. Diameter:  
up to .32 mm.

Anomalinoides costianus (Weinzierl and Applin)

## Plate 6, Figure 14

Anomalina costiana Weinzierl and Applin, 1929, Jour. Pal.  
Vol. 3, p. 409, pl. 44, figs. 7 a-c.'

Anomalina nodosa Hussey, 1943, Jour. Pal., Vol. 17, no. 2,  
p. 166, pl. 26, fig. 9-10.

Test unequally biconvex, ventrally convex, partially evolute; peripheral margin subangular to rounded; 10 to 11 chambers on the last formed coil; sutures gently curved; limbate in early stages, slightly depressed in later chambers; dorsal sutures thicken and end abruptly near the center where they form beaded circle; ventral sutures merge into low umbonal boss of clear shell material; aperture peripheral, extending onto the dorsal side with the length of last two chambers or so. Diameter: up to .28 mm.

Anomalinoides umbonatus (Cushman)

## Plate 6, Figure 15

Anomalina umbonata Cushman, 1925, Bull. Amer. Assoc. Petro.  
Geol. Vol. 9, p. 300, pl. 7, figs. 5, 6.

Test unequally biconvex or planoconvex, ventral side more convex, dorsal side flat, sometimes slightly concave; periphery subacutely rounded; about 12-13 chambers in the final whorl; last whorl is not completely involute in the portion of last few chambers; dorsal sutures distinct, radial, curved, flush with surface; umbonal area filled with low lying umbo of clear shell material; ventral sutures radial, strongly limbate, thickening toward the center but abruptly ended near the umbo, sometimes forming knob-like pillars surrounding distinct central umbo; aperture low peripheral

arch, extending onto the ventral side along the base of the last 3 chambers. Diameter: up to .51 mm.

Genus *Melonis* de Montfort, 1808

*Melonis planatus* (Cushman and Thomas)

Plate 6, Figure 16

*Nonion planatum* Cushman and Thomas, 1930, Jour. Pal, Vol. 4, p. 37, pl. 3, fig. 5 a-b.

Test almost circular in outline, slightly compressed, bilaterally symmetrical; biumbonate; periphery broadly rounded; 8-9 chambers in the final whorl; sutures radial, slightly curved, slightly depressed; wall smooth; finely perforate; aperture equatorial slit at the base of the last chamber. Diameter: up to .26 mm.

*Melonis* cf. *M. umblicatula* (Montegu) subsp. *pacifica*

Plate 6, Figure 17

*Nonionina umblicatula* (Montagu) var. *pacifica* Cushman, 1924, Carnegie Inst., Washington, Publ. no. 342 (Dept. Marine Biol., Papers), Vol. 21, p. 48, pl. 16, fig. 3.

Test somewhat ovate in outline, biumblicate, flattened; periphery gently lobulate; broadly rounded; chambers 8-9 in the final whorl; wall smooth; finely perforate; sutures distinct, slightly curved and depressed; aperture equatorial extending into umblicus. Diameter: up to .3 mm.

Family Ceratobuliminidae Cushman, 1927

Genus *Ceratobulimina* Toulou, 1915

*Ceratobulimina eximia* (Rzehak)

Plate 6, Figure 18

*Pulvinulina eximia* Rzehak, 1888, Ann. K. K. Nat. Hofmuseums, Vol. 3, pt. 3, p. 263, pl. 11, figs. 7 a-c.

Cerotobulimina limbata Hussey, 1949, Jour. Pal. Vol. 23,  
no. 2, p. 139, pl. 28, fig. 8-9.

Test large, smooth and polished, biconvex, finely perforate; periphery smoothly rounded; up to 9 chambers on the final whorl; umbilicate; sutures straight to slightly curved, depressed, incised near the center on the ventral side, somewhat limbate on spiral side; aperture large, comma-shaped in the last septal face open into umbilicus; may have rim around the portion near the umbilicus. Diameter: up to .67 mm.

Genus Lamarckina Berthelin, 1881

Lamarckina claibornensis Cushman

Plate 6, Figure 19

Lamarckina marylandica Cushman, var. claibornensis Cushman  
1926, Contro. Cushman Lab. Foram. Res., Vol. 2, p5. 1,  
p. 10 (type figure not given).

Lamarckina claibornensis Cushman var. gemmulate Hussey, 1949,  
Jour. Pal. Vol. 23, no. 2, p. 136, pl. 28, fig. 10.

Test subcircular, biconvex; sharply carinate; about 6-7 chambers on the final whorl gradually increasing in size; sutures on the ventral side indistinct, but slightly curved, depressed in later portion; heavily limbate; curved on the dorsal side, coalescing at the umbonal area; wall smooth, polished; aperture semicircular arch at the median portion of the base of the last chamber, more or less toward the umbilical region. Diameter: up to .47 mm.

Genus Hoeglundina Brotzen, 1948

Hoeglundina eocenica (Cushman and Hanna)

Plate 6, Figure 20

Epistomina eocenica Cushman and Hanna, 1927, Trans. San Diego Soc. Nat. Hist., Vol. 5, p. 53, pl. 5, figs. 4-5.

Epistomina chromata Hussey, 1949, Jour. Pal. Vol. 23, no. 2, p. 137, pl. 28, figs. 11-12.

Test unequally biconvex, more convex on the ventral side, circular in outline; periphery acute, bluntly carinate; 6 chambers on the final whorl; sutures distinct, thick, slightly elevated and whiter than the chamber wall; straight, radial, ventral sutures coalescing at the center of the ventral side in an umbilical thickening; aperture low interiomarginal slit, secondary aperture long, narrow slit on the distal end of each chamber, parallel to the periphery on the ventral side. Diameter: up to .44 mm.

Family Robertinidae Reuss, 1850

Genus Robertina d'Orbigny, 1846

Robertina plummerae Cushman and Parker

Plate 6, Figure 21

Robertina plummerae Cushman and Parker, 1938, Contr. Cushman Lab., Foram. Res., Vol. 14, pt. 4, p. 75, pl. 16, fig. 1.

Test about two and a half times as long as broad, greatest breadth around the middle, initial end gently tapering; chambers gradually increasing in size, about 6 pairs visible on apertural side; sutures slightly depressed; wall smooth, finely perforate; primary aperture elliptical slit extended over the apertural face from the base of the last chamber; narrow secondary aperture along the basal suture of the last chamber, almost as large as the primary. Length: up to .42 mm. Width: up to .12 mm.



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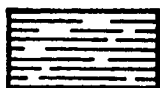
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## APPENDIX I. Description of Sampled Sections

## Legend to Lithologic Sections



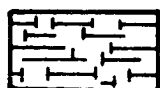
Clay



Silty Clay



Clay with Sand or Silt Partings



Marl



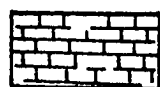
Massive Sand



Cross Bedded Sand



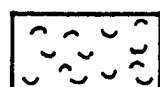
Glauconite



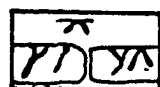
Limestone



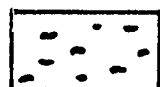
Micromollusks



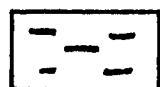
Oysters



Burrows



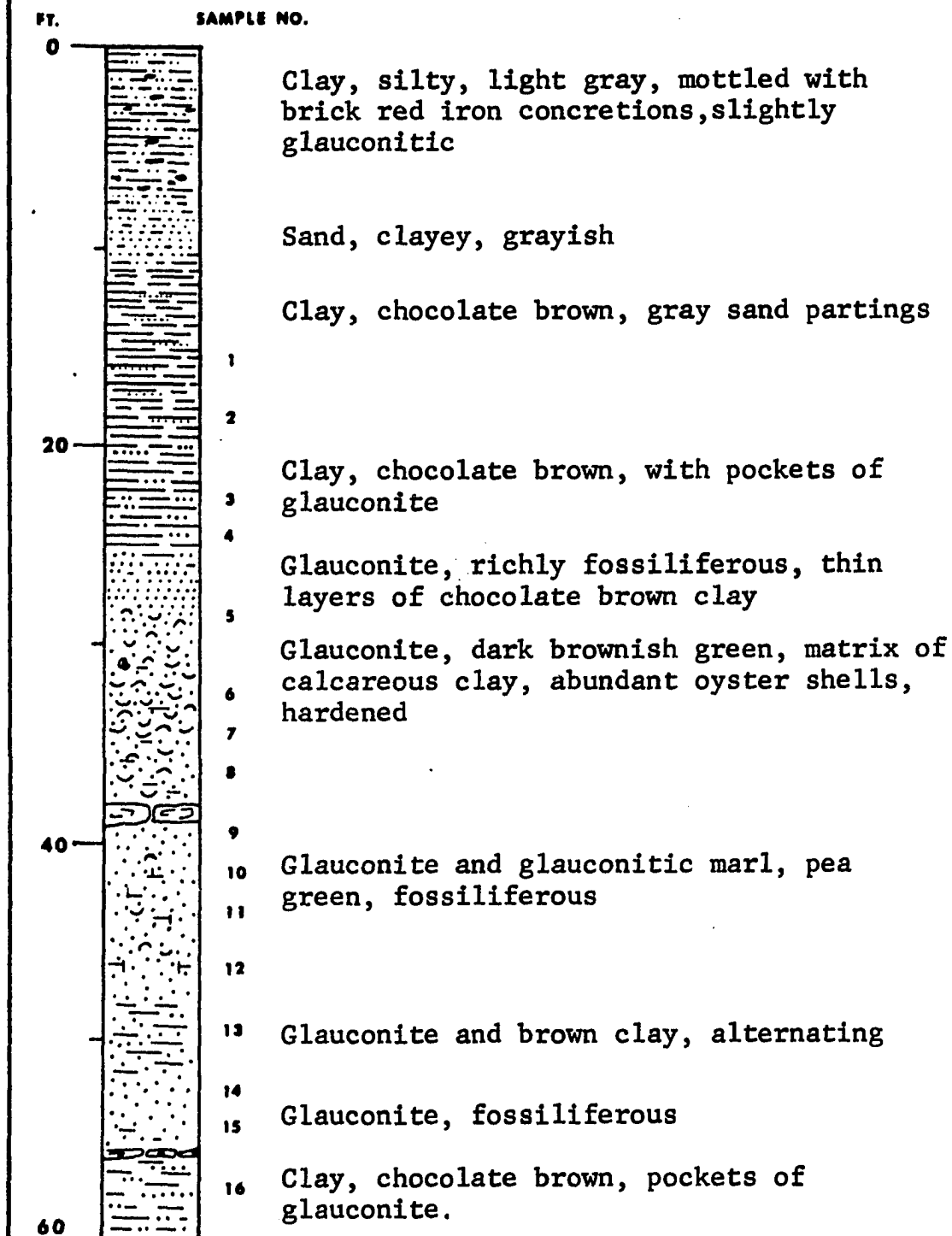
Oxidized Iron Concretions



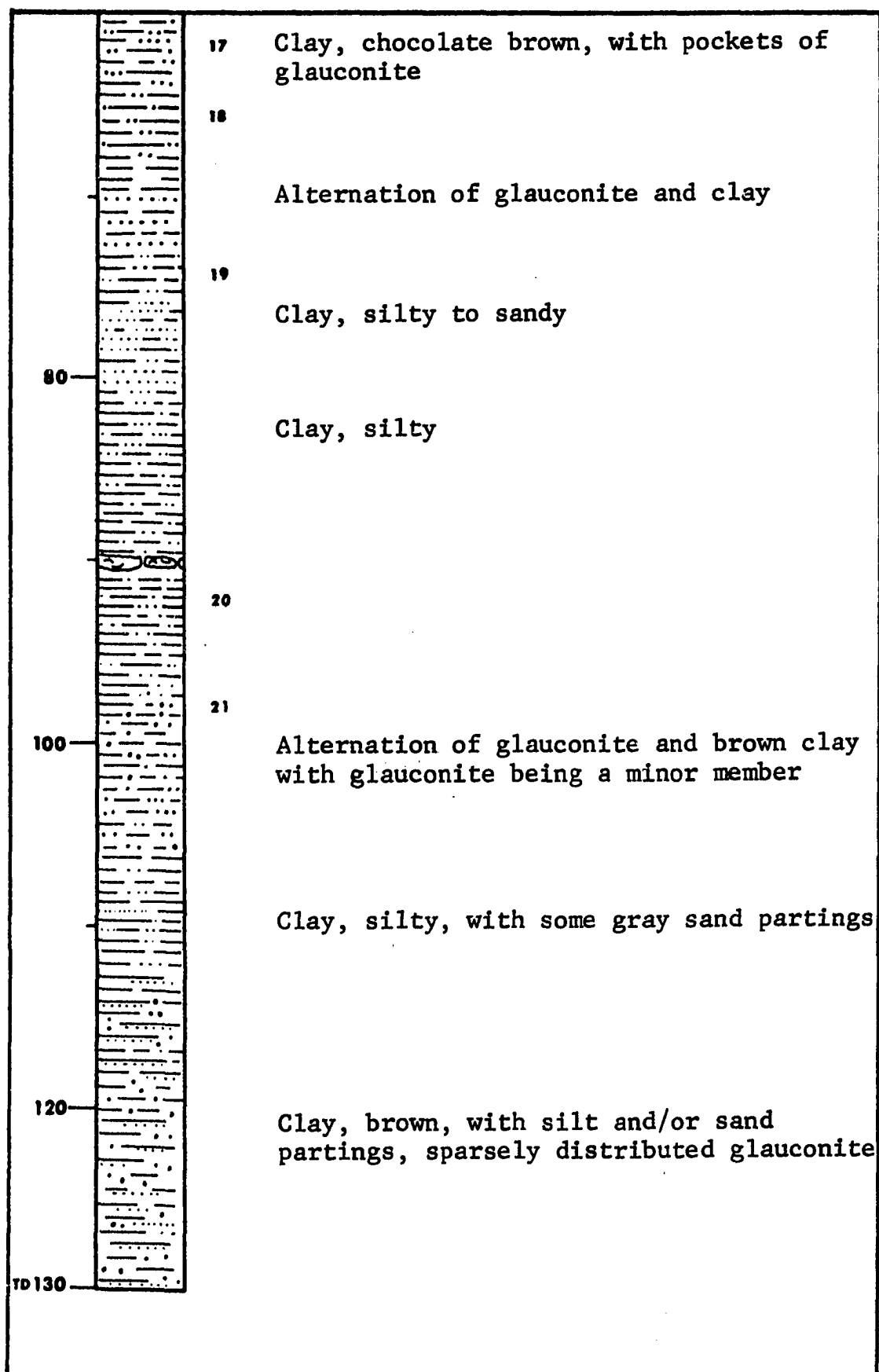
Lignite

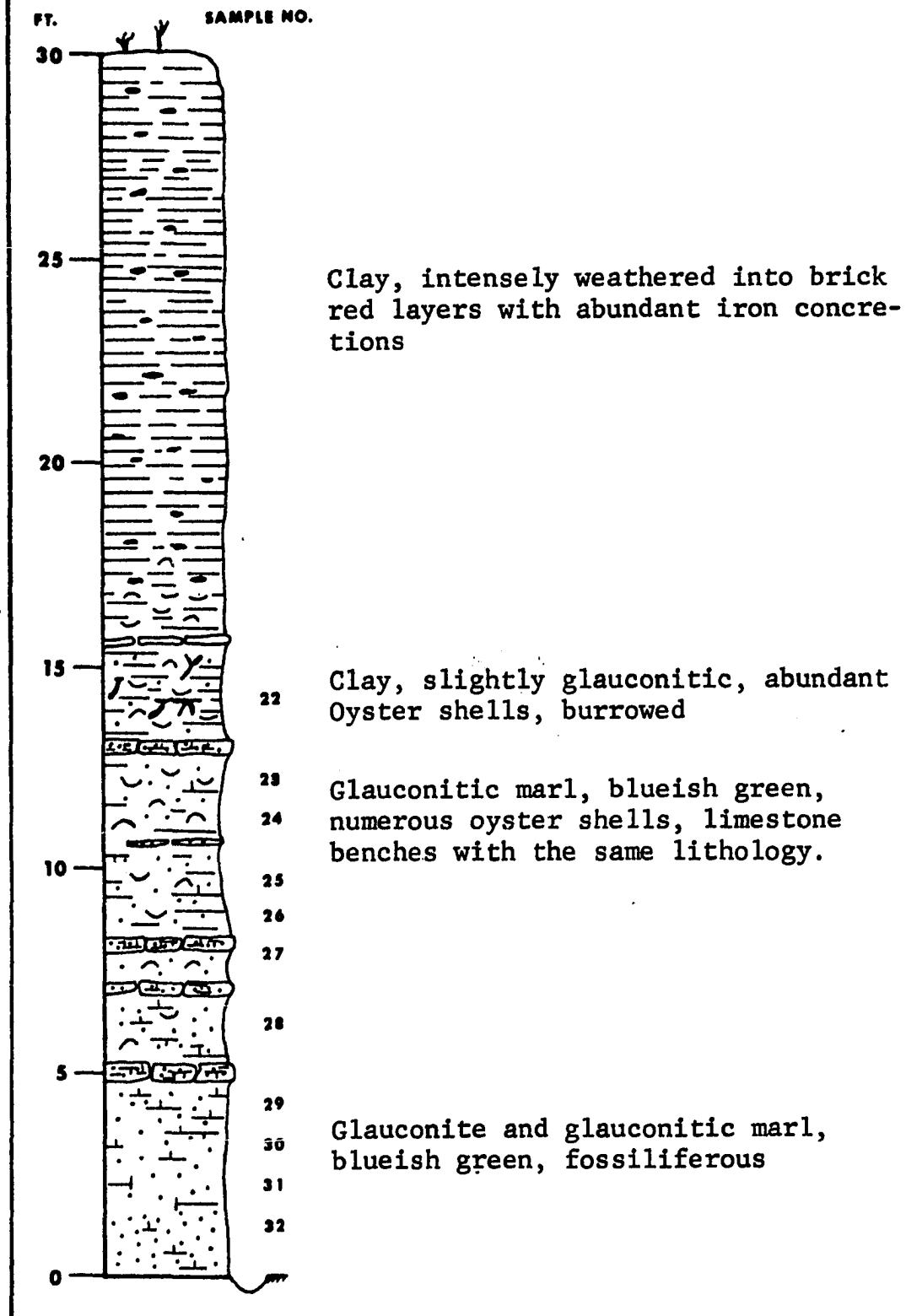


Pyrite Crystals

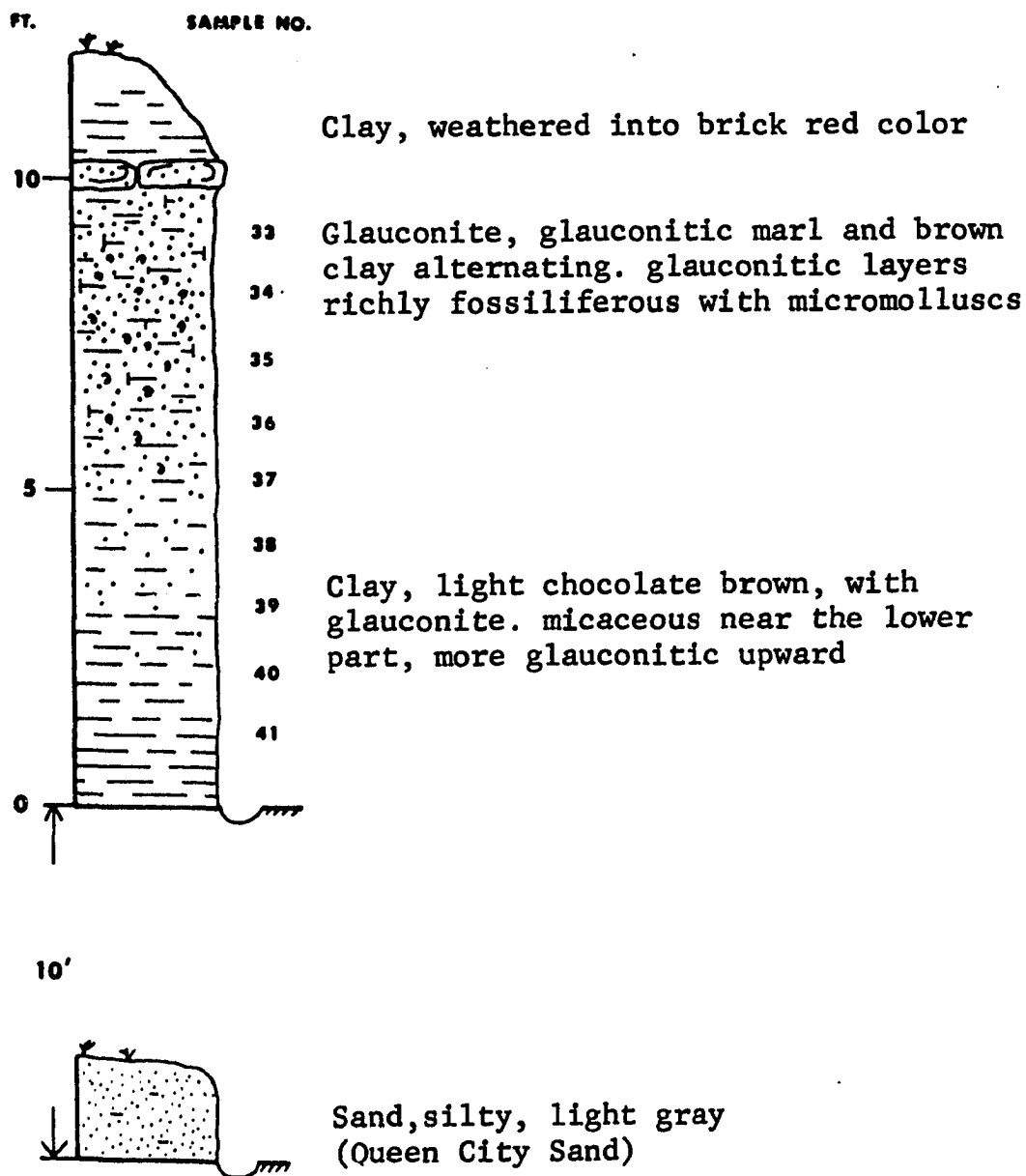
**1. WECHES****HOUSTON COUNTY, TEXAS**



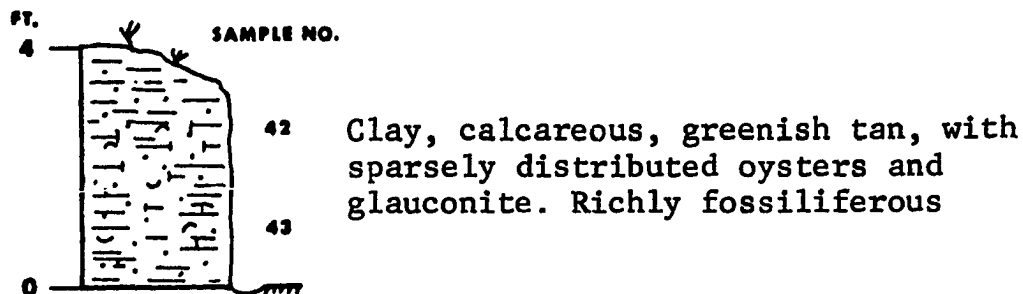


**2. PALESTINE****ANDERSON COUNTY, TEXAS**

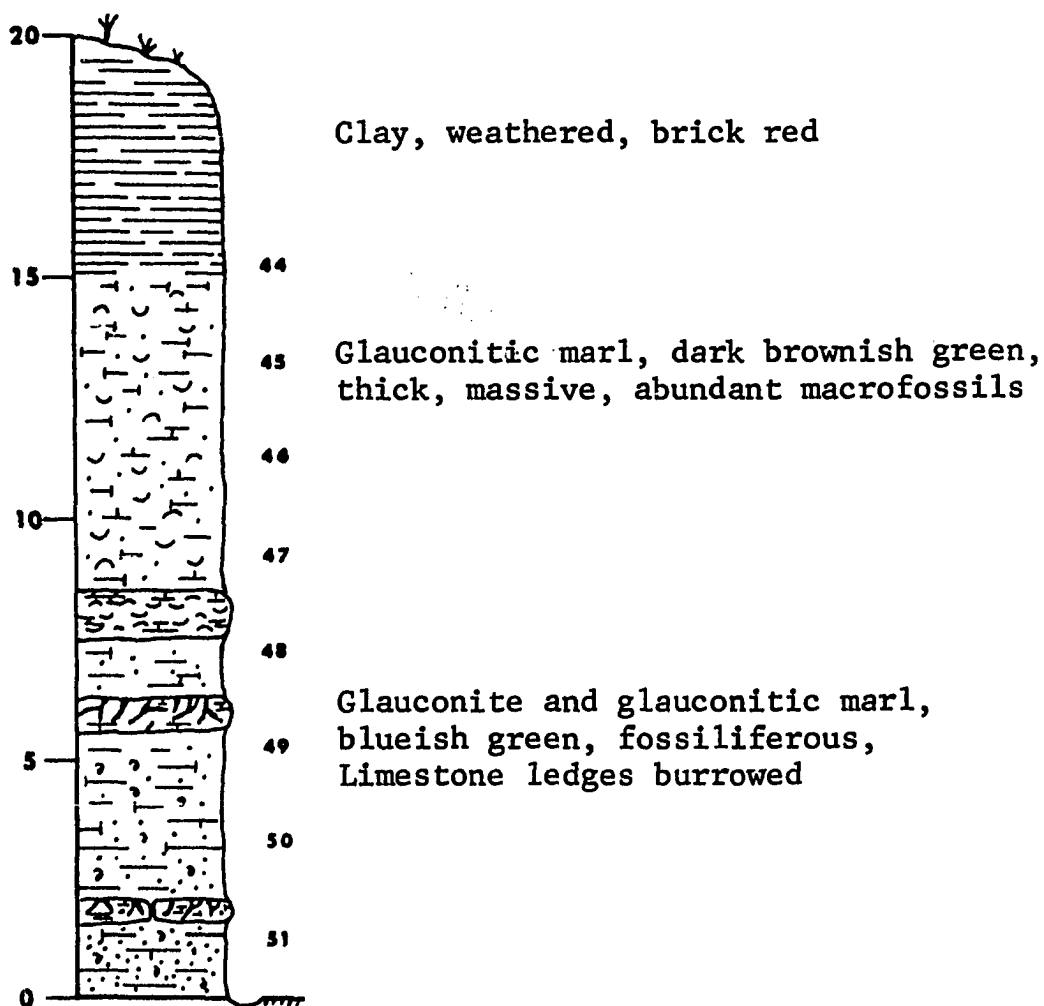
### 3. NACOGDOCHES NACOGDOCHES COUNTY, TEXAS



#### 4. BAYOU CARRIZO      NACOGDOCHES COUNTY, TEXAS

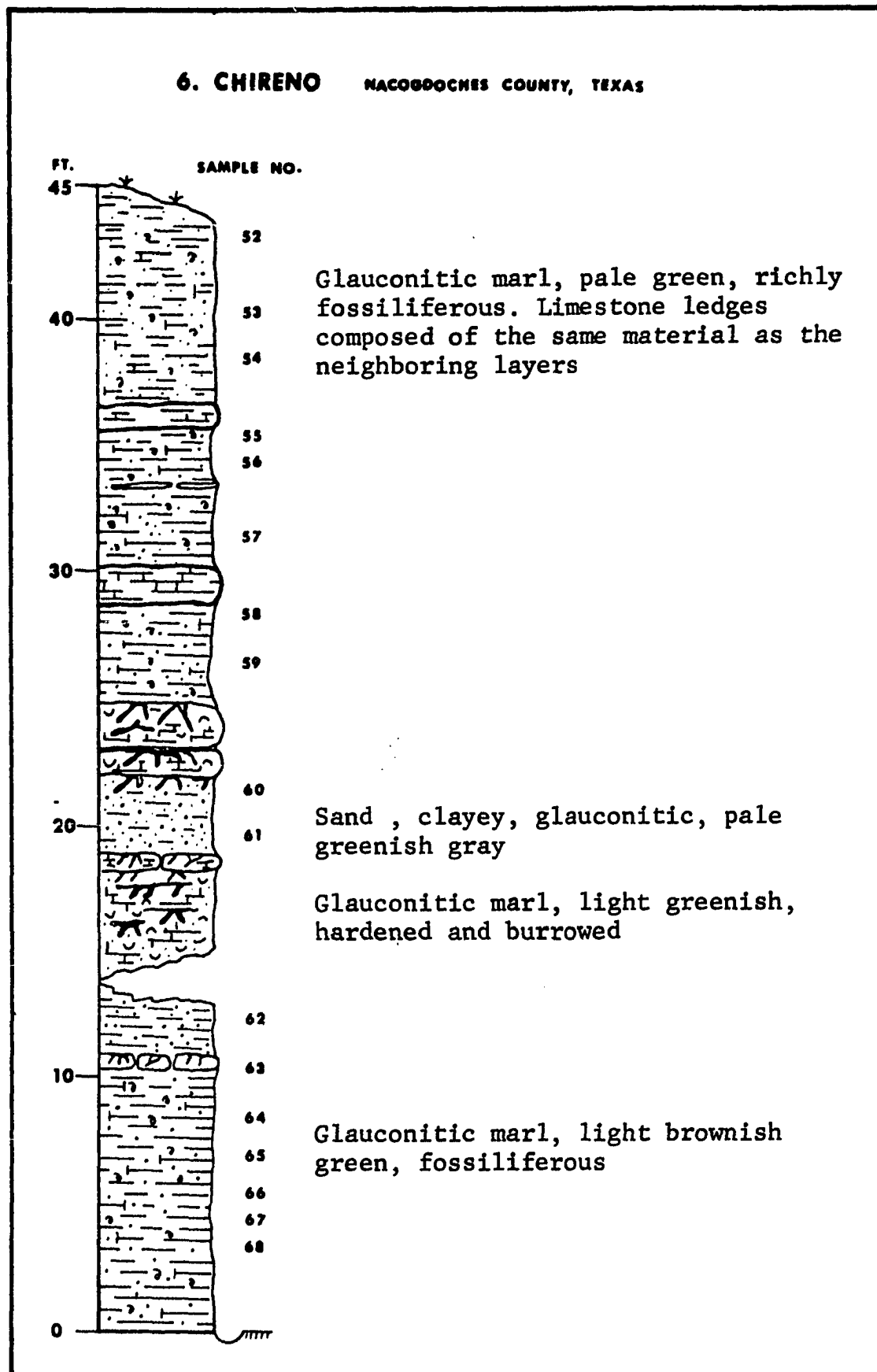


#### 5. CHIRENO II      NACOGDOCHES COUNTY, TEXAS



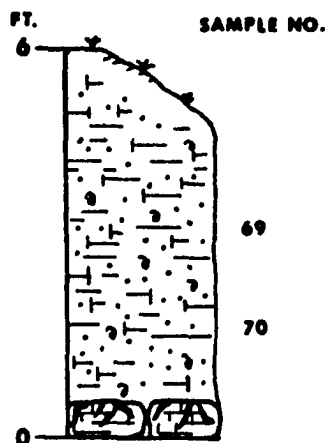
## 6. CHIRENO

MACOMB COUNTY, TEXAS



**7. BAYOU ATTOYAC**

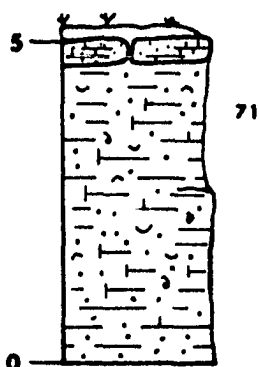
SAN AUGUSTINE COUNTY, TEXAS



Glauconitic marl, dark brown on weathered surface, bluish green on fresh break, richly fossiliferous

**8. SAN AUGUSTINE**

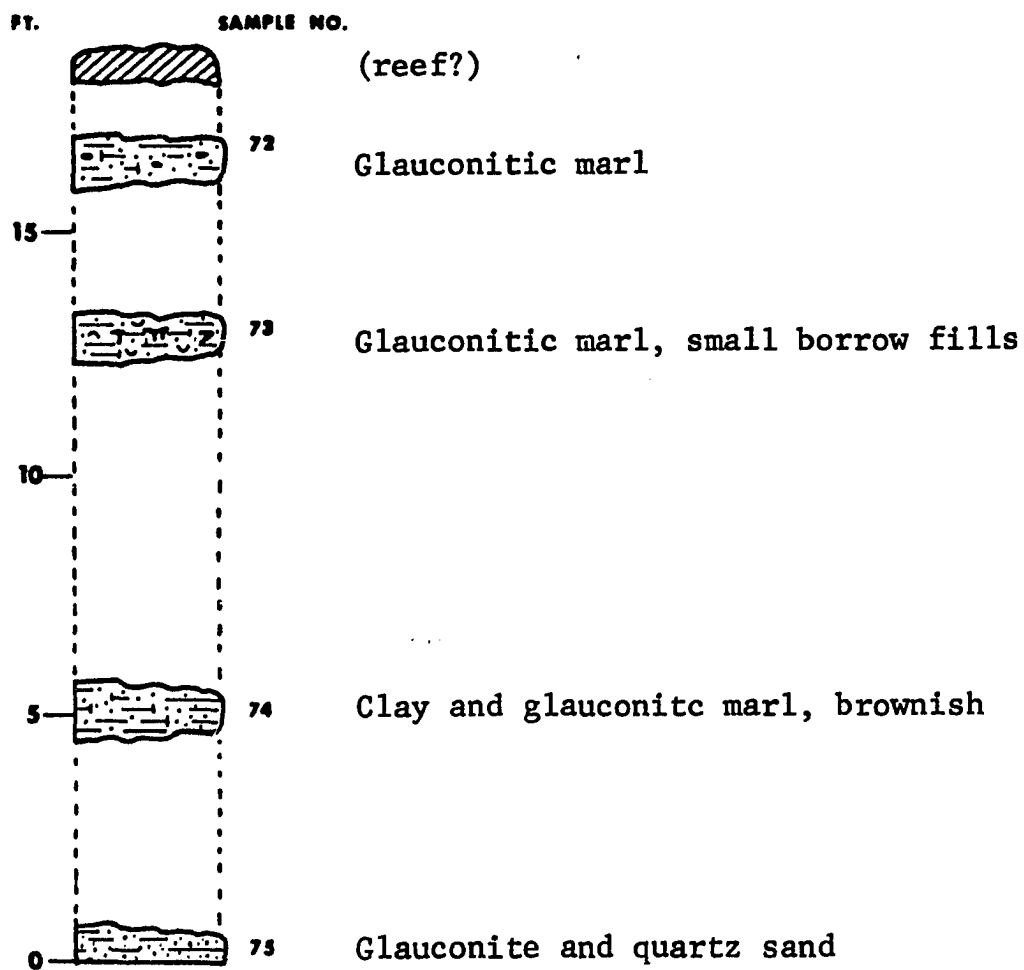
SAN AUGUSTINE COUNTY, TEXAS

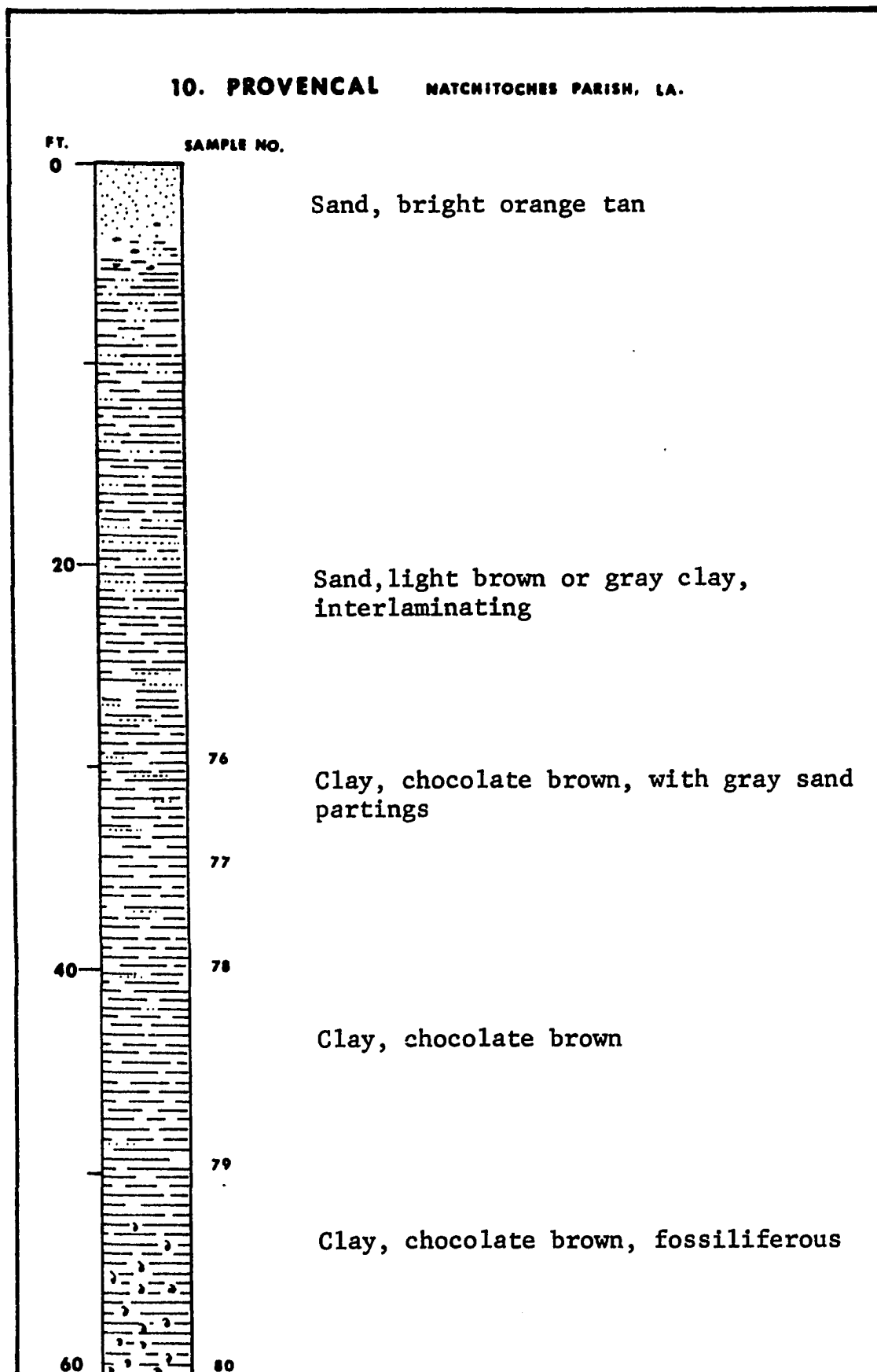


Glauconitic marl, intensely weathered into brownish gray color, richly fossiliferous but mostly leached out

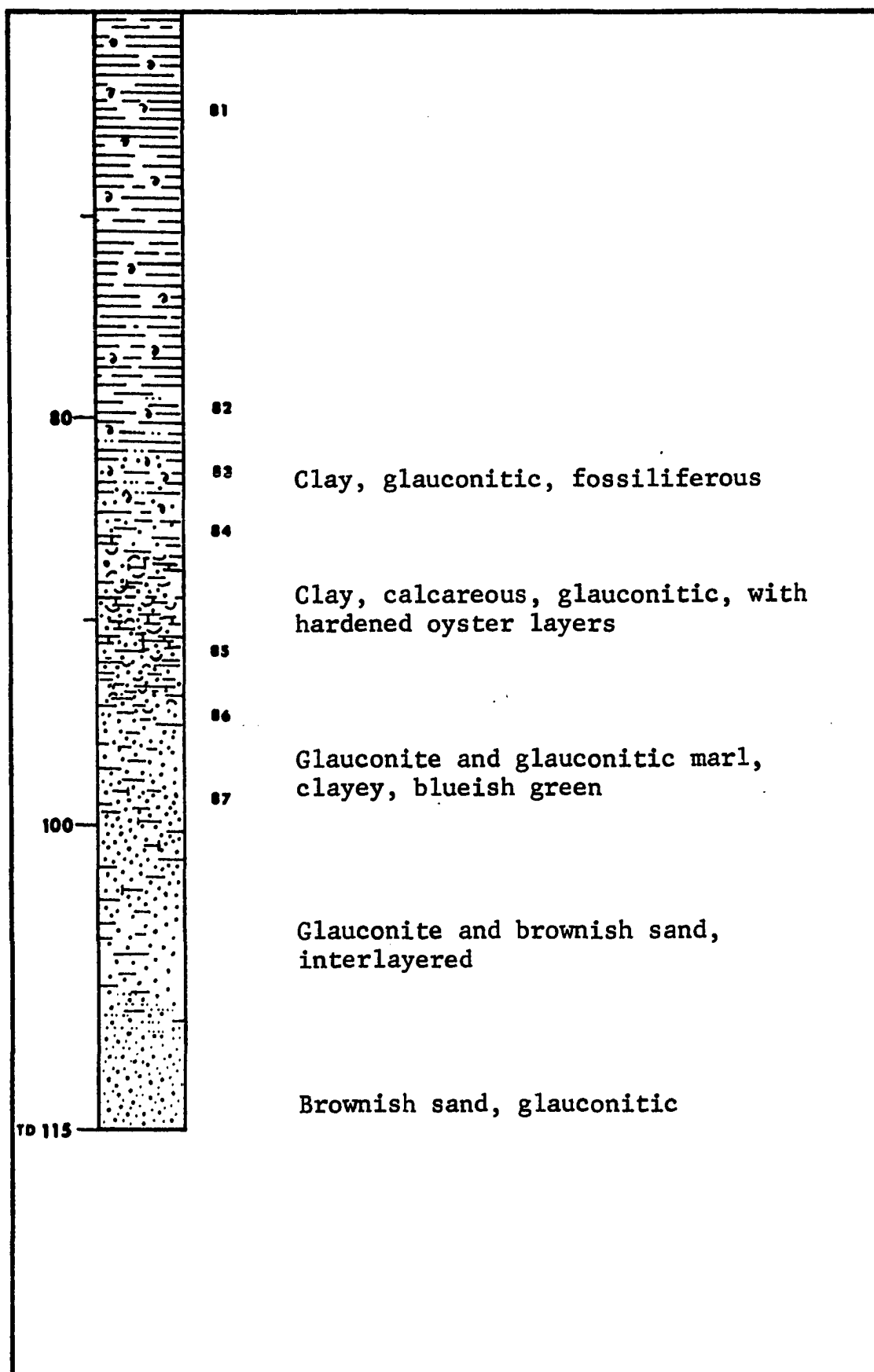
**9. BAYOU NEGREET**

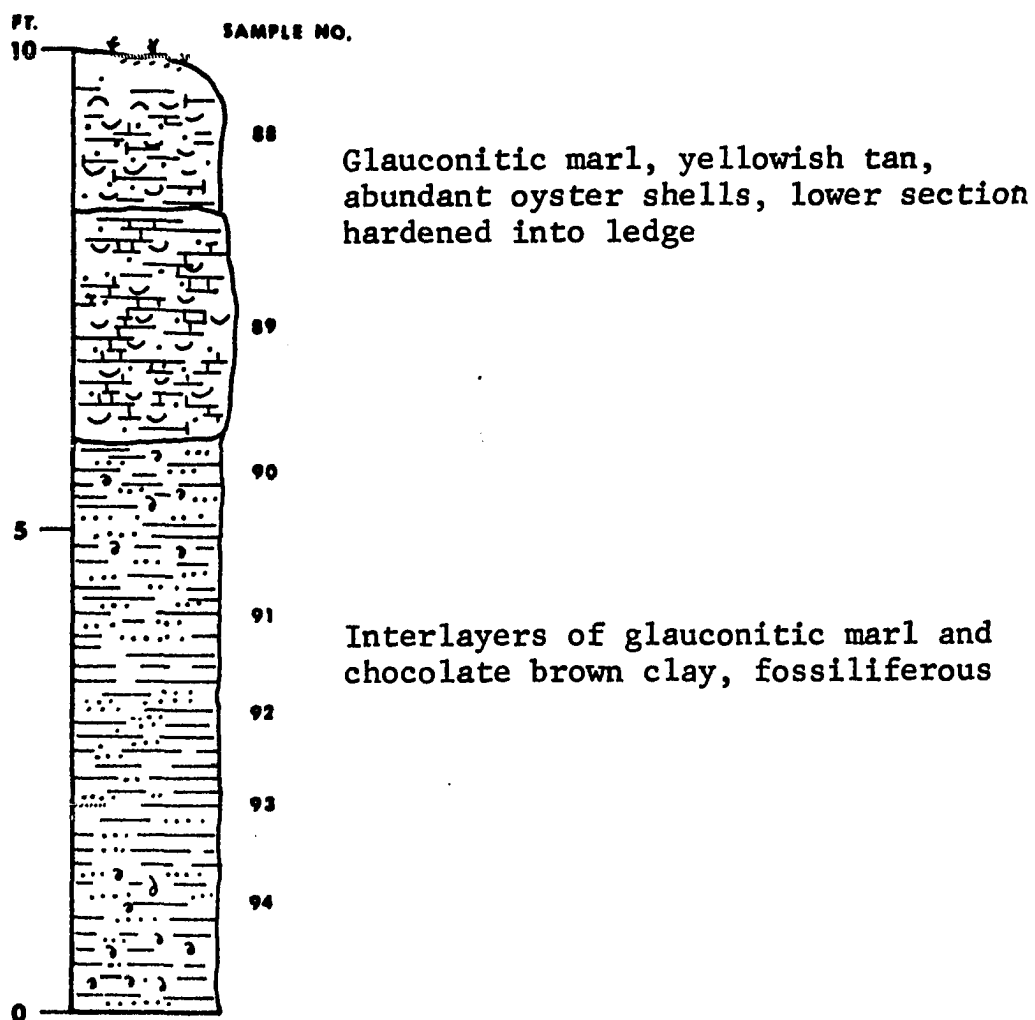
SABINE PARISH, LA.

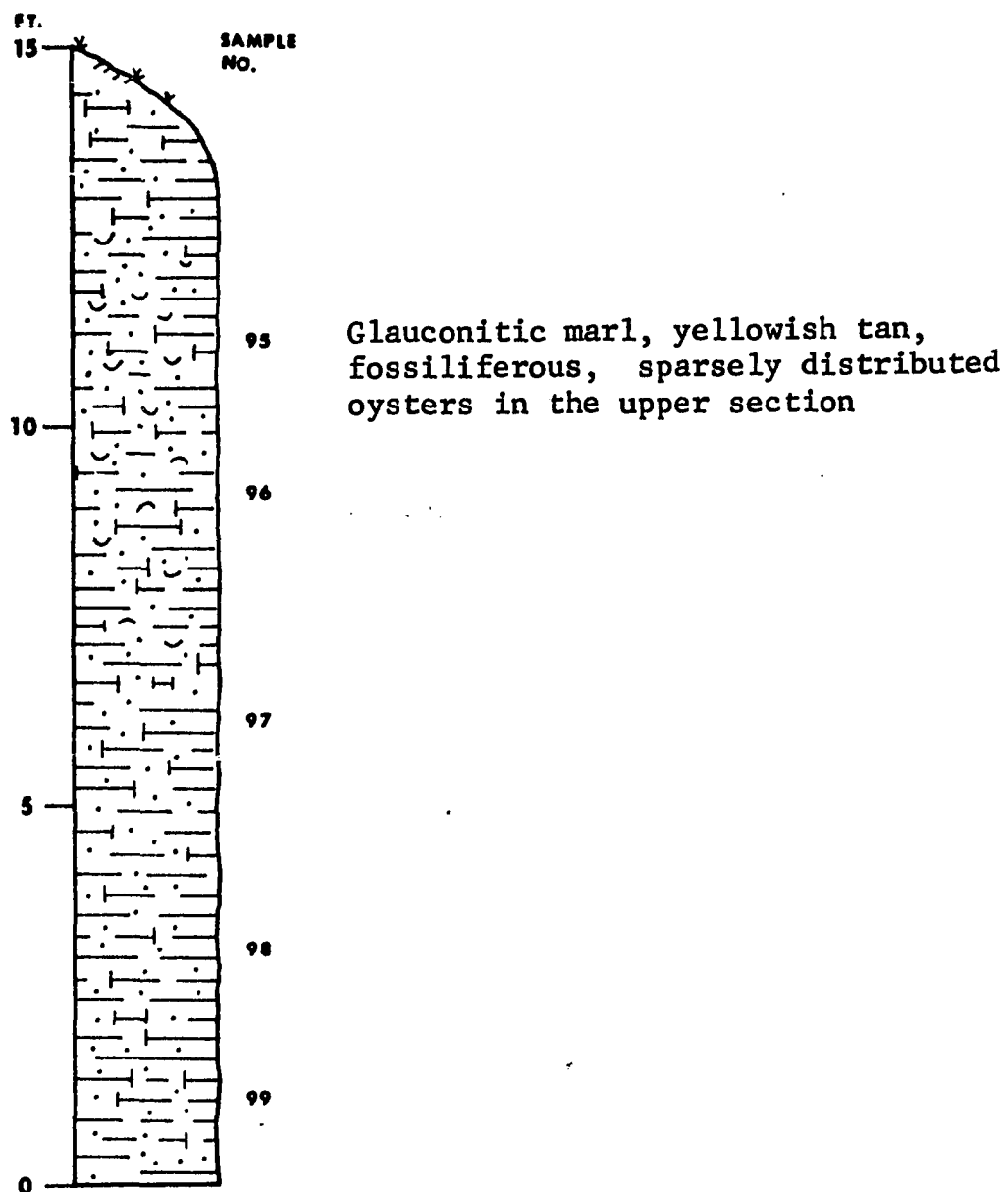




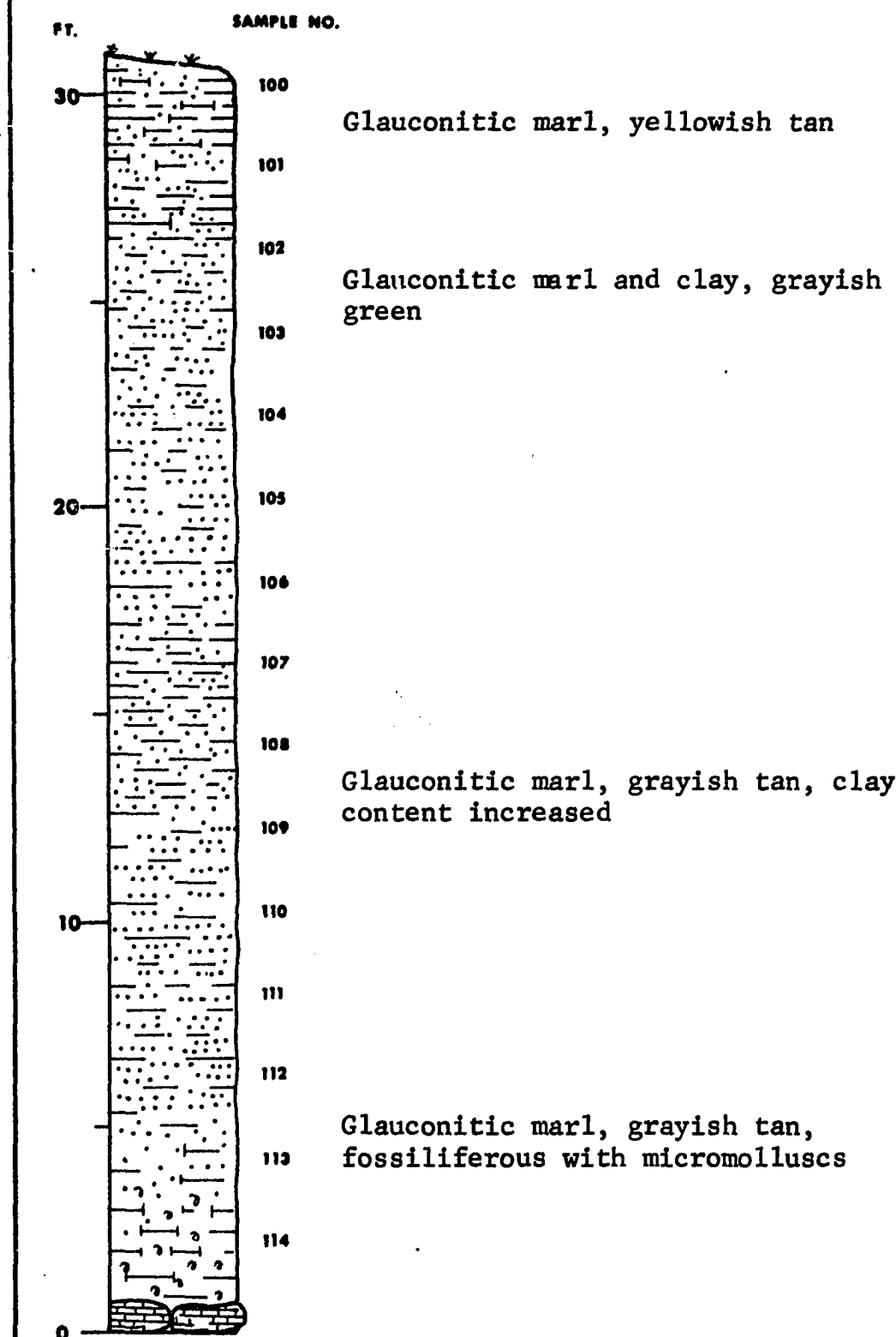




**11. HAGEWOOD      NATCHITOCHES PARISH, LA.**

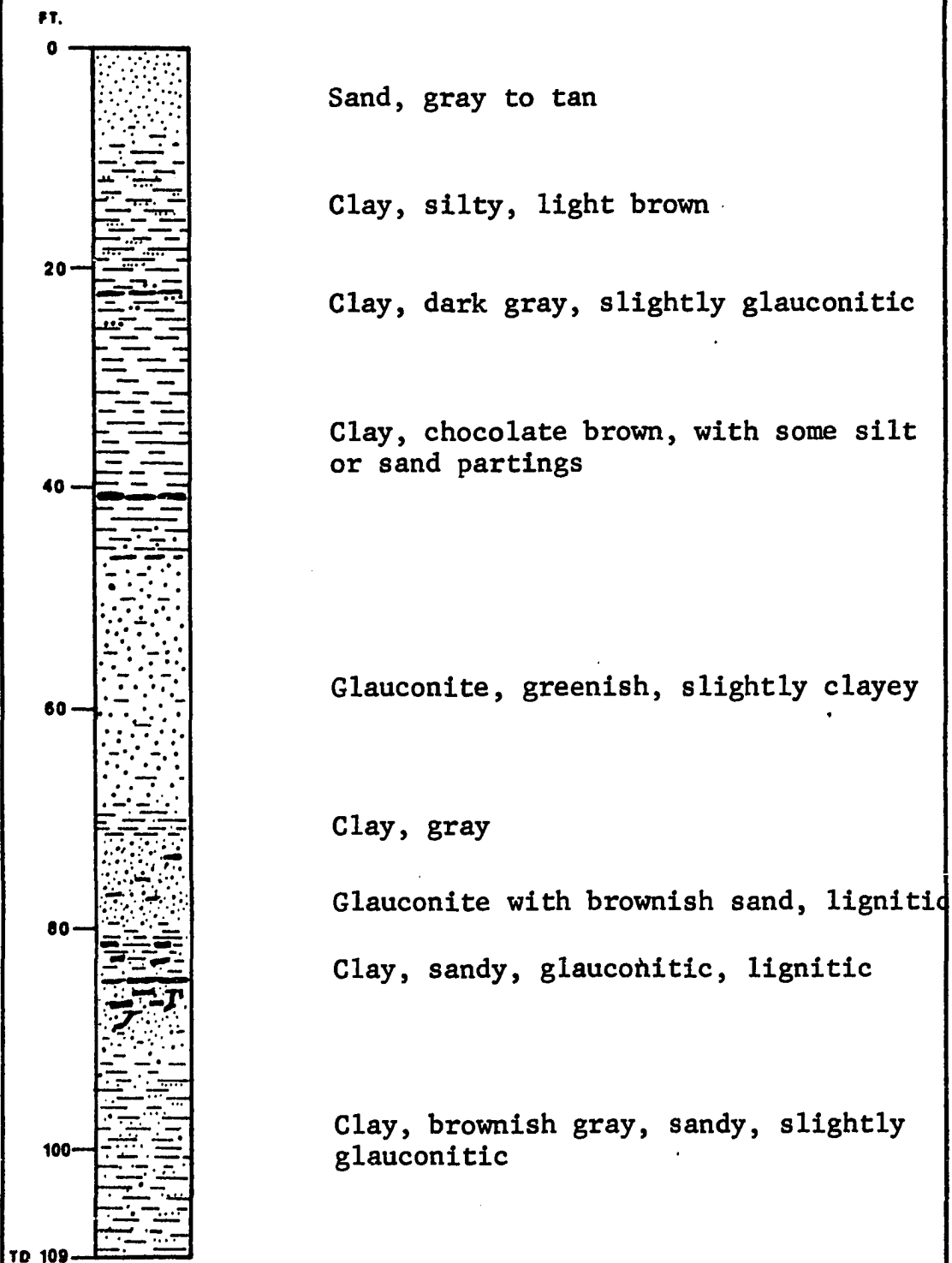
**12. CLEAR LAKE II NATCHITOCHES PARISH, LA.**

### 13. CLEAR LAKE      MATCHITOCHE PARISH, LA.



## 15. ROBELINE

NATCHITOCHES PARISH LA.



## APPENDIX II

Table of Frequency and Depth Range of Foraminiferal Species living in the Gulf of Mexico.

Genus and Species	Frequency	Depth Range
<u>Ammobaculites</u>		
<u>A. exiguss</u>	rare	Sound
<u>A. salsus</u>	common	Marsh-Inner neritic
<u>A. dilatatus</u>	rare	Sound-Inner neritic
<u>A. exillis</u>	abundant	Estuary
<u>A. angularis</u>	common	Inner neritic
<u>A. foliaceus</u>	rare	Inner neritic

Anomalinoides

\*A. mexicana rare 250-1,000m

\*Holotype figures and descriptions show that most probably this species does not belong to Anomalinoides.

Asterigerina

<u>A. carinata</u>	common- abundant	Middle neritic
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Bolivina and Brizalina

<u>Bolivina albatrossi</u>	common	250-1,200m
<u>B. barbata</u>	rare	50-350m 1,000-3,000m
<u>B. daggarius</u>	common	150-200m
<u>B. flagilis</u>	common	60-150m
<u>B. goësis</u>	rare	100-250m
<u>B. hastata</u>	rare	90-400m

Genus and Species	Frequency	Depth Range
<u>B. inflata</u>	rare	Inner neritic
<u>B. lowmani</u>	common	of all depths
<u>B. minima</u>	common	150-350m
<u>B. ordinaria</u>	common	150-750m
<u>B. pulchella</u>	rare	100m
<u>B. pulchella primitiv</u>	rare	Inner neritic
<u>B. spathulata</u>	rare	Inner neritic
<u>B. striatula</u>	rare	30-1,000m
<u>B. subaenariensis</u> <u>mexicana</u>	common- abundant	100-350m
<u>B. cf. subexcavata</u>	rare	Inner neritic
<u>B. subspinescens</u>	rare	50-1,000m
<u>Bulimina</u>		
<u>B. aculeata</u>	common	500-2,500m
<u>B. alazamensis</u>	common	500-1,000m
<u>B. marginata</u>	rare	400m
<u>B. spicata</u>	common	400-1,000m
<u>B. striata mexicana</u>	common	450-2,000m
<u>B. tenuis</u>	rare	80-120m
<u>Cibicides</u>		
<u>C. americanus</u> <u>strattoni</u>	rare	Littoral
<u>C. concentricas</u>	rare	80-120m
<u>C. copulentus</u>	rare	100-1,000m
<u>C. floridanus</u>	abundant	60-100m up to 1,000m

Genus and Species	Frequency	Depth Range
<u>C. deprimus</u>	rare	40-200m
<u>C. io</u>	rare	150m
* <u>C. kullenberg</u>	rare	1,000m
<u>C. lobatulus</u>	rare	beach
<u>C. molli</u>	rare	40-200m
<u>C. protuberans</u>	abundant	100-250m
<u>C. pseudoungerianus</u>	abundant	80-130m
<u>C. robertsonianus</u>	rare	500-250m
<u>C. umbonatus</u>	rare	90-350m
* <u>C. wuellostorfi</u>	rare	700-3,000m
*Probably <u>Planulina</u>		
<u>Cibicidina</u>		
* <u>Hanzawaia strattoni</u>	abundant	10-100m
* <u>H. concentrica</u>	abundant	10-100m
* <u>H. bertheloti</u>	rare	100-200m
*See remarks in the chapter of Bathymetry and Environment		
<u>Cyclammina</u>		
<u>C. cancellata</u>	common	450-2,000m
<u>Discorbis</u>		
<u>D. bertheloti</u>	rare	30-200m
<u>D. bulbosa</u>	rare	< 200m
* <u>D. concinna</u>	common	=35
<u>D. cf. cocinna</u>	common	beach
<u>D. cf. columbiensis</u>	common	Inner neritic
<u>D. floridana</u>	common	<100m



Genus and Species	Frequency	Depth Range
<u>D. floridensis</u>	rare	100-200m
<u>D. suezensis</u>	rare	<350m
*May be <u>Eponides</u>		
<u>Gyroidinoides</u>		
<u>G. soldanii</u> <u>altiformis</u>	common	200-3,000m
<u>Gyroidina orbicularis</u>	common	200-3,000m
<u>Haplophragmoides</u>		
<u>H. manilaensis</u>	common	marsh
<u>H. subinvelutum</u>	common	marsh-sound
<u>H. wilberti</u>	common	marsh
<u>H. canariensis mexicana</u>	rare	Littoral
<u>H. bradyi</u>	common-present	500-3,000m 90-3,000m
<u>Lamarckina</u>		
<u>L. atlantica</u>	rare	Littoral
<u>Lenticulina</u>		
<u>L. peregrina</u>	rare	50-1,500m
<u>L. calcar</u>	common	10-200m
<u>Melonis</u>		
* <u>Nonion barlceana</u>	rare	=150m
* <u>N. formosum</u>	rare	70-1,500m
* <u>N. germaicum</u>	rare	Transitional
* <u>N. pauciloculum</u>	rare	Transitional
* <u>N. pompilioides</u>	rare	30-3,000m

Genus and Species	Frequency	Depth Range
* <u>N. cf. pompilioides</u>	rare	=150m
<u>N. depressulum</u>	rare	bay
<u>N. depressulum</u> <u>matagordana</u>	rare	Littoral
<u>N. cf. granosum</u>	rare	Transitional
<u>N. cf. grateloupi</u>	rare	<100m
* <u>Melonis</u> . Also see remarks in the Chapter of Bathymetry and Environment		

### Neoeponides

<u>N. antillarum</u>	common	=120m
<u>Eponides hannai</u>	rare	Inner neritic
<u>E. regularis</u>	common-abundant	150-400m
<u>E. repandus</u>	rare-common	<200m
<u>E. polius</u>	rare	>500m
<u>E. tumidulus</u>	abundant	1,500-3,000m
<u>E. turgidus</u>	rare	200-3,000m

### Quinqueloculina

<u>Q. agglutinans</u>	rare	Inner neritic
<u>Q. akneriana</u>	abundant	bay
<u>Q. auberiana</u>	rare	Littoral
<u>Q. bicostata</u>	common	±40m
<u>Q. bosciana</u>	rare	Inner neritic
<u>Q. condeiana</u>	common	Inner neritic
<u>Q. cataliensis</u>	rare	Inner neritic
<u>Q. compata</u>	common	Inner neritic
<u>Q. costata</u>	common	Inner neritic

Genus and Species	Frequency	Depth Range
<u>Q. cultrata</u>	common	Inner neritic
<u>Q. dutemplei</u>	rare	Inner neritic
<u>Q. faunafutiensis</u>	rare	Inner neritic
<u>Q. horrida</u>	common	±40m
<u>Q. jugosa</u>	rare	Inner neritic
<u>Q. lamarkiana</u>	rare	bay
<u>Q. poeyana</u>	rare	Inner neritic
<u>Q. rhodiensis</u>	rare	sound
<u>Q. sabulosa</u>	rare	bay
<u>Q. seminulum</u>	common	Inner neritic
<u>Q. subpoeyana</u>	rare	bay
<u>Q. subquadra</u>	rare	=30m
<u>Q. vulgaris</u>	rare	Inner neritic

#### Siphonina

<u>S. pulchra</u>	rare-common	80-500m
<u>S. bradyana</u>	rare	40-750m

#### \*Spiroplectamina

<u>S. floridana</u>	rare	80-200m
<u>T. agglutians</u>	rare	Littoral
<u>T. candeiana</u>	common	Inner neritic
<u>T. conica</u>	rare	<200m
<u>T. earlandi</u>	rare-abundant	<100m
<u>T. foliacea</u> <u>occidentalis</u>	rare	30-200m
<u>T. gramen</u>	rare	Inner neritic

Genus and Species	Frequency	Depth Range
<u>T. mayori</u>	rare-common	<60m
<u>T. mexicana</u>	rare	100-350m
<u>T. pseudotrochus</u>	rare	60-80m
<u>Trifarina</u>		
<u>T. bella</u>	rare	120m
<u>T. bradyi</u>	rare	0-2,000m
<u>Triloculina</u>		
<u>T. bassensis</u>	rare	bay
<u>T. bermudezi</u>	rare	bay
<u>T. brevidentata</u>	rare	< 200m
<u>T. carinata</u>	rare	bay
<u>T. fiterrei</u>	rare	bay
<u>T. linneiana</u>	rare	bay
<u>T. oblonga</u>	rare	bay
<u>T. sidebottomi</u>	rare	Inner neritic
<u>T. squamosa</u>	rare	<30m
<u>T. striatotrigonula</u>	rare	bay
<u>T. trigonula</u>	common	Inner neritic
<u>Trochammina</u>		
<u>T. comprimata</u>	rare-common	Transitional
<u>T. globulosa</u>	common	1,000-3,000m
<u>T. inflata</u>	abundant	Transitional
<u>T. cf. laevigata</u>	rare	Inner neritic
<u>T. cf. lobata</u>	rare	Inner neritic
<u>T. macrescens</u>	common	Transitional

Genus and Species	Frequency	Depth Range
<u>T. cf. ochracea</u>	common	Inner neritic
<u>T. quadriloba</u>	rare	100-300m
<u>T. squamata</u>	rare	Inner neritic
<u>Uvigerina</u>		
<u>U. auerianae</u> var. <u>laevis</u>	common	80-150m
<u>U. bellula</u>	rare	80-200m
<u>U. flinti</u>	common	100-350m
<u>U. hispido-costata</u>	common	200-700m
<u>U. laevis</u>	rare	up to 3,000m
<u>U. parvula</u>	rare	80-350m
<u>U. peregrina</u>	common	100-1,800m
<u>U. peregrina parvula</u>	rare	> 50m

## APPENDIX III

## LIST OF OSTRACODA SPECIES AND THEIR REFERENCES

Acanthocythereis cf. washburni (Stephenson) pl. 7, fig. 1

Cythereis washburni Stephenson, Jour. Pal. Vol. 18,  
no. 5, 1944, p. 452, pl. 76, fig. 8.

Acanthocythereis species A pl. 7, fig. 2

Acanthocythereis species B pl. 7, fig. 3

Actinocythereis davidwhitei (Stadnichenko) pl. 1, fig. 4

Cythereis davidwhitei Stadnichenko, Jour. Pal. Vol. 1,  
no. 3, 1927, p. 240, pl. 39, fig. 24

Actinocythereis (?) elmana (Stadnichenko) pl. 1, fig. 5

Cythereis elmana Stadnichenko, Jour. Pal. Vol. 1, No. 3,  
1927, p. 240, pl. 39, fig. 20

Actinocythereis cf. hilgardi (Howe and Garrett) pl. 1, fig. 6

Cythereis hilgardi Howe and Garrett, Louisiana Dept.  
Cons., Geol. Bull. No. 4, 1934, p. 53, pl. 4,  
figs. 14, 15.

Actinocythereis species pl. 1, fig. 7

Bairdia species pl. 1, figs. 8, 9, 10

Brachycythere species pl. 1, fig. 11

Buntonia howei (Stephenson) pl. 1, fig. 12

Pyriocythereis howei Stephenson, Jour. Pal. Vol. 20,  
no. 4, 1946, p. 330, pl. 42, figs. 16, 17

Buntonia alabamensis (Howe and Pyeatt) pl. 1, fig. 13

Cythereis (?) alabamensis Howe and Pyeatt, Louisiana  
Dept. Cons. Geol. Bull. no. 4, 1934, p. 50, pl. 4,  
figs. 2, 5, 7-10

Bythocypris gibsonensis Howe and Chambers pl. 1, fig. 14

Bythocypris gibsonensis Howe and Chambers, Louisiana  
Dept. Cons. Geol. Bull. no. 5, 1935, p. 9, pl. 3,  
fig. 10, pl. 4, fig. 3

Clithrocytheridea wechensis (Stephenson) Stephenson pl. 8, fig. 1

Cytheridea (Clithrocytheridea) subpyriformis Sutton and Williams, var. wechensis Stephenson, Jour. Pal. Vol. 16, 1942, p. 113, pl. 18, fig. 14

Clithrocytheridea wechensis (Stephenson) Stephenson, Jour. Pal. Vol. 20, 1946, p. 329, pl. 42, fig. 19

Clithrocytheridea species pl. 8, fig. 2

Coccolitha smithvillensis (Stephenson) pl. 8, fig. 3

Cytheridea (Clithrocytheridea) smithvillensis Stephenson, Jour. Pal. Vol. 16, no. 1, p. 113, 1942, pl. 18, fig. 2

"Cythereis" evergreenica (Stadnichenko) pl. 8, fig. 4

Cythere evergreenica Stadnichenko, Jour. Pal. Vol. 1, no. 3, 1927, p. 235, pl. 39, fig. 25

"Cythereis" russelli Howe and Garrett

Cythereis russelli Howe and Garrett, Louisiana Dept. Cons. Geol. Bull. no. 4, 1934, p. 54, pl. 4, fig. 11

"Cythereis" suttoni Stephenson pl. 8, fig. 5

Cythereis suttoni Stephenson (new name) Jour. Pal. Vol. 20, no. 4, 1946, p. 340

Pyricythereis smithvillensis Sutton and Williams, Jour. Pal. Vol. 13, no. 6, 1939, p. 568, pl. 64, figs. 16-19

Cytherella species pl. 8, fig. 6

Cytherelloidea smithvillensis Howe pl. 8, fig. 7

Cytherelloidea smithvillensis Howe, Jour. Pal. Vol. 8, no. 1, 1934, p. 30-31, pl. 5, fig. 3

Cytherura (?) species pl. 8, fig. 8

Digmyocythere russelli (Howe and Lea) pl. 8, fig. 9

Brachyocythere russelli Howe and Lea, Louisiana Dept. Cons. Geol. Bull. no. 7, 1936, p. 41, pl. 2, figs. 30, 31

Haplocytheridea bastropensis (Sutton and Williams) pl. 8, fig. 10

Cytheridea (Haplocytheridea) bastropensis Sutton and Williams (new name) Jour. Pal. Vol. 14, no. 2, 1940, p. 163

Cytheridea (Haplocytheridea) subovata Sutton and Williams, Jour. Pal. Vol. 13, no. 6, 1939, p. 569, pl. 64, figs. 26-28.

Haplocytheridea lisbonensis (Stephenson) pl. 8, fig. 11

Cytheridea (Haplocytheridea) lisbonensis Stephenson, Jour. Pal. Vol. 16, no. 1, 1942, p. 168, pl. 18, figs. 11, 12.

Haplocytheridea ellisi Stephenson pl. 8, fig. 12

Haplocytheridea ellisi Stephenson, Jour. Pal. Vol. 20, no. 4, p. 322, pl. 42, fig. 21

Haplocytheridea habropapillosa (Sutton and Williams) pl. 8, fig. 13

Cytheridea (Haplocytheridea) habropapillosa Sutton and Williams, Jour. Pal. Vol. 13, no. 6, 1939, p. 570, pl. 64, figs. 20-22.

Haplocytheridea moodyi (Howe and Garrett) pl. 8, fig. 14

Cytheridea moodyi Howe and Garrett, Louisiana Dept. Cons. Geol. Bull. no. 4, 1934, p. 35-36, pl. 2, figs. 2-6

Haplocytheridea stuckeyi (Stephenson) pl. 9, fig. 1

Cythereis studkeyi Stephenson (new Name), Jour. Pal., Vol. 21, no. 6, 1947, p. 580

Cythereis (?) elongata Sutton and Williams, Jour. Pal. Vol. 13, no. 6, 1939, p. 565, pl. 64, figs. 31-33

Hemicytheridea (?) species pl. 9, fig. 2

Hermanites (?) claibornensis (Gooch) pl. 9, fig. 3

Cythereis claibornensis Gooch, Jour. Pal. Vol. 13, no. 6, 1939, pl. 581, pl. 67, figs. 5, 6, 10

Loxoconcha chamfera Murray pl. 9, fig. 4

Loxoconcha chamfera Murray, Jour. Pal. Vol. 12, no. 6, 1938, p. 588, pl. 68, figs. 3, 18

Loxoconcha claibornensis Murray pl. 9, fig. 5

Loxoconcha claibornensis Murray, Jour. Pal. Vol. 12, no. 6, 1938, p. 588, pl. 68, figs. 2, 19.



Ouachitaia gosportensis (Stephenson) pl. 9, fig. 6

Cytheridea (Clithrocytheridea) gosportensis Stephenson, Jour. Pal. Vol. 16, no. 1, 1942, p. 111, pl. 18, figs. 5, 6

Ouachitaia semireticulata (Stephenson) pl. 9, fig. 7

Cytheridea (Clithrocytheridea) semireticulata Stephenson, Jour. Pal. Vol. 16, no. 1, 1942, p. 112, pl. 18, figs. 15, 16

Opimocythere martini (Murray and Hussey) pl. 9, fig. 8

Brachyocythere martini Murray and Hussey, Jour. Pal. Vol. 16, no. 2, 1942, p. 177, pl. 28, figs. 6, 10

Paracypris franquesi Howe and Chambers pl. 9, fig. 9

Paracypris franquesi Howe and Chambers, Louisiana Dept. Cons. Geol. Bull. no. 5, 1935, p. 10-11, pl. 3, fig. 13

Pterygocythere bernardi (Murray and Hussey) pl. 9, fig. 10

Brachyocythere bernardi Murray and Hussey, Jour. Pal. Vol. 16, no. 2, 1942, p. 176-177, pl. 28, figs. 7, 9; Test. fig. 2, figs. 14, 15, 16

Pterygocythere murrayi Hill pl. 9, fig. 11

Pterygocythere murrayi Hill, Jour. Pal. Vol. 28, no. 6, 1954, p. 822, pl. 100, figs. 5a-c

Quadracythere winniana (Gooch) pl. 9, fig. 12

Cythereis winniana Gooch, Jour. Pal. Vol. 13, no. 6, 1939, p. 582-583, pl. 67, figs. 4, 9

Trachylebereis (?) linospinosa (Sutton and Williams) pl. 9, fig. 13

Cythereis linospinosa Sutton and Williams, Jour. Pal. Vol. 13, no. 6, 1939, p. 566, pl. 63, figs. 5, 6

Trachyleberis orelliana (Stadnichenko) pl. 9, fig. 14

Cythere orelliana Stadnichenko, Jour. Pal. Vol. 1, no. 3, p. 236-237, 1927, pl. 39, figs. 8-10

Xestoleberis dumblei Stephenson pl. 9, fig. 15

Xestoleberis dumblei Stephenson, Jour. Pal. Vol. 20, no. 4, 1946, p. 320, pl. 43, fig. 16

## APPENDIX IV

## Regression Equations

## 1. Weches

## Cibicides

$$Y = .32559639 + .02537313x - .00048363x^2 + .00000265x^3$$

$$R^2 = .37508251 \quad = .05$$

## Milliolidae

$$Y = -.09179922 + .02036624x^2 - .00000765x^3 + .0000004x^4$$

$$R^2 = .14110864$$

## Discorbis

$$Y = .52443338 + .04146701x - .00075587x^2 + .00000397x^3$$

$$R^2 = .33539241 \quad = .1$$

## Siphonina

$$Y = .73914826 + .0609276x - .00119330x^2 + .00000665x^3$$

$$R^2 = .56187714 \quad = .05$$

## Lamarckina

$$Y = .03559446 + .00000222x^3 - .00000002x^4$$

$$R^2 = .17170073 \quad = .1$$

## Asterigerina

$$Y = -.03823072 + .00000241x^3 - .00000002x^4$$

$$R^2 = .21728.45 \quad = .05$$

## Planktonics

$$Y = -13.57295297 + .98554140x - .01777557x^2 + .00009324x^3$$

$$R^2 = .16137102$$

## 2. Palestine

## Alabamina

$$Y = .12466894 - .02556104x + .00119613x^2$$

$$R^2 = .82240228 \quad = .05$$

## Neoeponides

$$Y = .00173132 + .01768448x + .00005800x^3$$

$$R^2 = .49372269 \quad = .05$$

## Lamarckina

$$Y = -.01565618 + .01250429x$$

$$R^2 = .69084699 \quad = .05$$

## Asterigerina

$$Y = -.03612469 + .00012772x^3$$

$$R^2 = .73746389 \quad = .05$$

## Discorbis

$$Y = .34386403 - .01980459x$$

$$R^2 = .64489316 \quad = .05$$

## Siphonina

$$Y = .17335945 + .07105193x - .00535442x^2$$

$$R^2 = .71365646 \quad = .05$$

## 3. Nacagdoches

## Discorbis

$$Y = .14017902 - .00018865x^3$$

$$R^2 = .34511626 \quad = .1$$

## Cibicides

$$Y = .01087987 + .00361983x^2 - .00039240x^3$$

$$R^2 = .55751426 \quad = .05$$

## Lamarckina

$$Y = .29417383 - .02247765x$$

$$R^2 = .22962431$$

## Gyroidinoides

$$Y = .20473601 + .09369965x - .00144088x^3$$

$$R^2 = .89626686 = .05$$

## 4. Chireno II

## Neoeponides

$$Y = .00291780 + .00047589x^2$$

$$R^2 = .51476548 = .05$$

## Lamarckina

$$Y = .17377533 - .04480316x + .00261190x^2$$

$$R^2 = .72241403 = .05$$

## Siphonina

$$Y = .09931980 + .01030943x$$

$$R^2 = .49491526 = .1$$

## Milliolidae

$$Y = .13631174 + .12092700x - .00743840x^2$$

$$R^2 = .52506538 = .1$$

## Discorbis

$$Y = .60793890 - .10508363x + .00560384x^2$$

$$R^2 = .68192034 = .05$$

## Planktonics

$$Y = .13095238 + .03081232x^2$$

$$R^2 = .50741232$$

## 5. Chireno

## Milliodae

$$Y = .27124296 - .00000348x^3$$

$$R^2 = .74503385 \quad = .05$$

## Asterigerina

$$Y = -.13315337 + .03315310x - .0001375x^2$$

$$R^2 = .23061384 \quad = .1$$

## Lamarckina

$$Y = .06204167 + .00000259x^3$$

$$R^2 = .33428242 \quad = .05$$

## Cibicides

$$Y = .05128004 + .01238502x - .00030642x^3$$

$$R^2 = .63489693 \quad = .05$$

## Planktonics

$$Y = 4.20974270 + .0006046x^3$$

$$R^2 = .16218062$$

## 6. Bayou Negreet

## Lamarckina

$$Y = .18536126 - .01853994x + .00002543x^3$$

$$R^2 = .99999101$$

## Anomalinoidea

$$Y = .03172802 + .00034570x^2$$

$$R^2 = .91211838 \quad = .05$$

## Siphonina

$$Y = .12478557 + .00116531x^2 - .00005568x^3$$

$$R^2 = .56244151$$

## Gyroidinoides

$$Y = .05394143 + .00073524x^2$$

$$R^2 = .96237213 = .05$$

## Cibicides

$$Y = .34622090 + .00221924x^2 - .00014990x^3$$

$$R^2 = .99852783 = .05$$

## Planktonics

$$Y = 12.13238291 + .33529340x^2 - .01686656x^3$$

$$R^2 = .90842909$$

## 7. Provençal

## Cibicidina

$$Y = -.00947968 + .00000006x^3$$

$$R^2 = .52557196 = .05$$

## Alabamina

$$Y = .00849214 + .00000007x^3$$

$$R^2 = .38524205$$

## Lenticulina

$$Y = -.06199241 + .00157772x$$

$$R^2 = .33331254 = .05$$

## Gyroidinoides

$$Y = .05428493 - .00006401x^2 + .00000073x^3$$

$$R^2 = .71956173 = .05$$

## Cibicides

$$Y = -.01642732 + .00000017x^3$$

$$R^2 = .68380410 = .05$$

## Anomalinoides

$$Y = -.03231215 - .00002234x^2$$

$$R^2 = .55814125 = .05$$

## Siphonina

$$Y = -.05753319 + .00003395x^2$$

$$R^2 = .73854695 \quad = .05$$

## Planktonics

$$Y = 24.86305110 - 1.14853932x + .01226446x^2$$

$$R^2 = .80430690 \quad = .1$$

## 8. Hagerwood

## Uvigerina

$$Y = .00033495 + .00006188x^3$$

$$R^2 = .60859216 \quad = .05$$

## Trifarina

$$Y = .07671726 - .02890903x + .00263902x^2$$

$$R^2 = .91907792 \quad = .05$$

## Lenticulina

$$Y = .04950149 + .00010077x^3$$

$$R^2 = .67237591 \quad = .05$$

## Cibicides

$$Y = .11485345 + .12545606x - .03930032x^2 + .00282695x^3$$

$$R^2 = .9653448 \quad = .05$$

## Anomalinoidea

$$Y = .11057844 + .00827641x$$

$$R^2 = .19301814$$

## Siphonina

$$Y = .08864112 + .00236743x^2$$

$$R^2 = .52358489 \quad = .1$$

## Planktonics

$$Y = 36.35684927 - 30.5586137x + 9.12295226x^2$$

$$R^2 = .77249683$$

## 9. Clear Lake II

## Uvigerina

$$Y = .08131901 - .02048291x + .00123947x^2$$

$$R^2 = .99237350 \quad = .05$$

## Anomalinoidea

$$Y = .13348072 + .01016642x - .00059079x^2$$

$$R^2 = .16487704$$

## Cibicides

$$Y = .11163771 + .00010796x^3$$

$$R^2 = .78231297 \quad = .05$$

## Siphonina

$$Y = .28867272 - .04208123x + .00263719x^2$$

$$R^2 = .71723925$$

## Planktonics

$$Y = 14.29741379 - 2.17272167x + .8736847x^2 - .06250000x^3$$

$$R^2 = .58877704$$

## 10. Clear Lake

## Lenticulina

$$Y = .07834111 - .00011211x^2$$

$$R^2 = .51557119 \quad = .05$$

## Cibicidina

$$Y = .06237178 - .00000282x^3$$

$$R^2 = .33834539 \quad = .05$$



## Gyroidinoides

$$Y = .12677022 - .02564746x + .00234657x^2 - .00005518x^3$$

$$R^2 = .18207611$$

## Cibicides

$$Y = .17519274 - .00021084x^2$$

$$R^2 = .37764208 \quad = .05$$

## Anomalinooides

$$Y = .08986554 + .00000855x^3$$

$$R^2 = .39769381 \quad = .05$$

## Siphonina

$$Y = .21454009 + .00088252x^2 - .00002440x^3$$

$$R^2 = .20728667$$

## Planktonics

$$Y = 38.48303623 - .03512555x^2$$

$$R^2 = .56870947 \quad = .05$$

## APPENDIX V (A)

## Reference for Sample Identification

<u>Locality &amp; Sample No.</u>	<u>Code</u>	<u>Locality &amp; Sample No.</u>	<u>Code</u>
1. Weches		2. Palestine	
1	10116		
2	10119	22	10201
3	10123	23	10203
4	10125	24	10205
5	10129	25	10206
6	10133	26	10207
7	10135	27	10208
8	10137	28	10210
9	10140	29	10212
10	10142	30	10213
11	10144	31	10214
12	10147	32	10215
13	10150	3. Nacogdoches	
14	10153	33	10301
15	10155	34	10302
16	10158	35	10303
17	10162	36	10304
18	10166	37	10305
19	10175	38	10306
20	10193	39	10307
21	10199	40	10308

<u>Locality &amp; Sample No.</u>	<u>Code</u>	<u>Locality &amp; Sample No.</u>	<u>Code</u>
41	10309	64	10640
4. Bayou Carrizo		65	10642
42	10401	66	10643
43	10403	67	10644
5. Chireno II		68	10645
44	10501	7. Bayou Attoyac	
45	10503	69	10701
46	10505	70	10703
47	10507	8. San Augustine	
48	10509	71	10801
49	10511	9. Bayou Negreet	
50	10513	72	20901
51	10515	73	20905
6. Chireno		74	20913
52	10603	75	20918
53	10608	10. Provencal	
54	10610	76	21030
55	10613	77	21035
56	10614	78	21040
57	10617	79	21050
58	10620	80	21060
59	10622	81	21065
60	10627	82	21080
61	10629	83	21083
62	10636	84	21086
63	10638	85	21092

<u>Locality &amp; Sample No.</u>	<u>Code</u>	<u>Locality &amp; Sample No.</u>	<u>Code</u>
86	21095	13. Clear Lake	
87	21099	100	21302
11. Hagewood		101	21304
88	21101	102	21306
89	21103	103	21308
90	21104	104	21310
91	21106	105	21312
92	21107	106	21314
93	21109	107	21316
94	21111	108	21318
12. Clear Lake II		109	21320
95	21201	110	21322
96	21203	111	21324
97	21206	112	21326
98	21209	113	21328
99	21211	114	21330

Sample No. used only for Taxonomic description

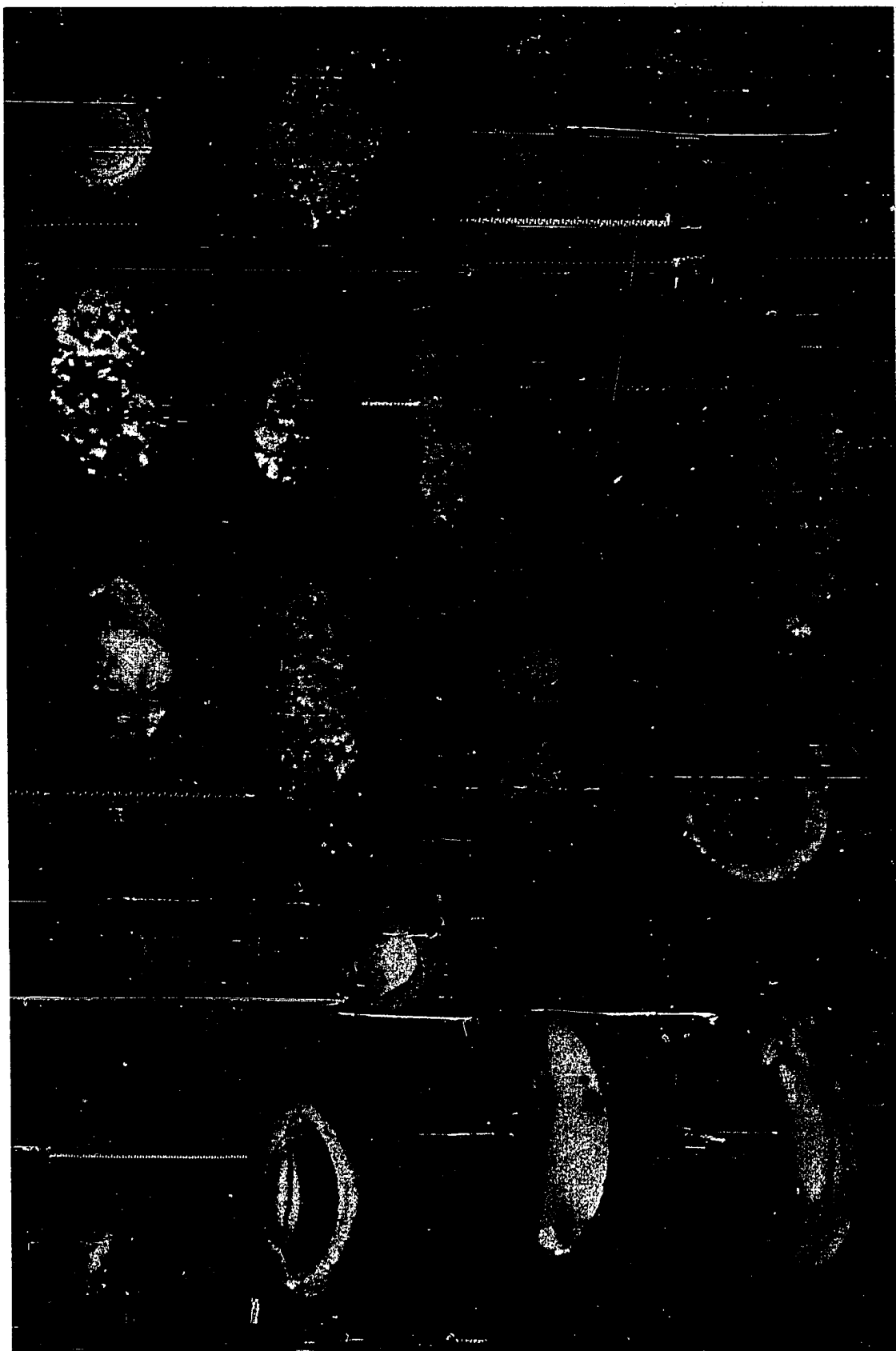
<u>Sample No.</u>	<u>Depth (Feet)</u>	<u>Sample No.</u>	<u>Depth (Feet)</u>
115	1468	122	1482
116	1470	123	1483
117	1472	124	1486
118	1473	125	1487
119	1476	126	1488
120	1479	127	1490
121	1480	128	1491

<u>Sample No.</u>	<u>Depth (Feet)</u>	<u>Sample No.</u>	<u>Depth (Feet)</u>
129	1496	133	1531
130	1498	134	1533-1538
131	1499	135	1551-1552
132	1503-1509	136	1553-1555

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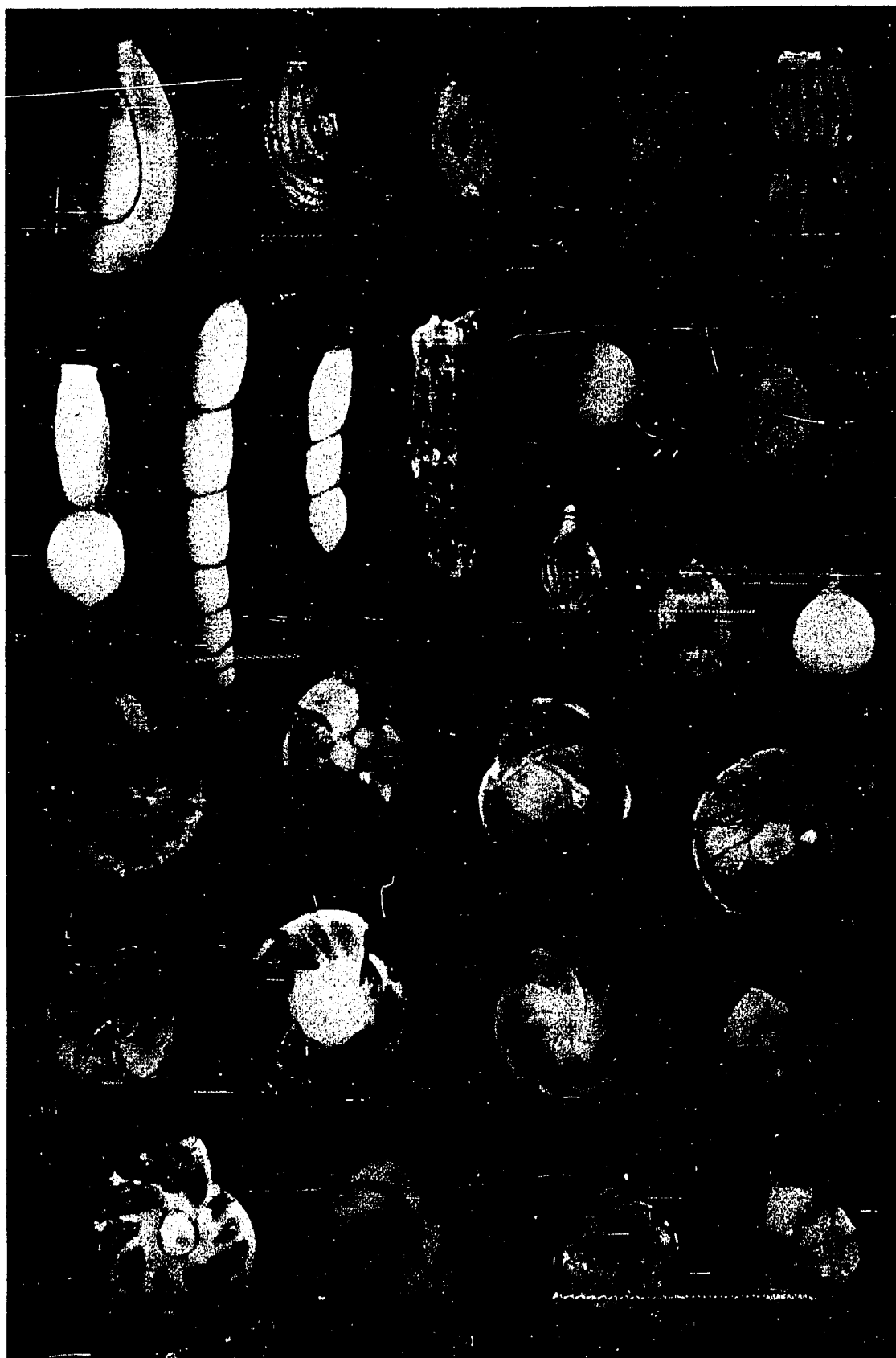
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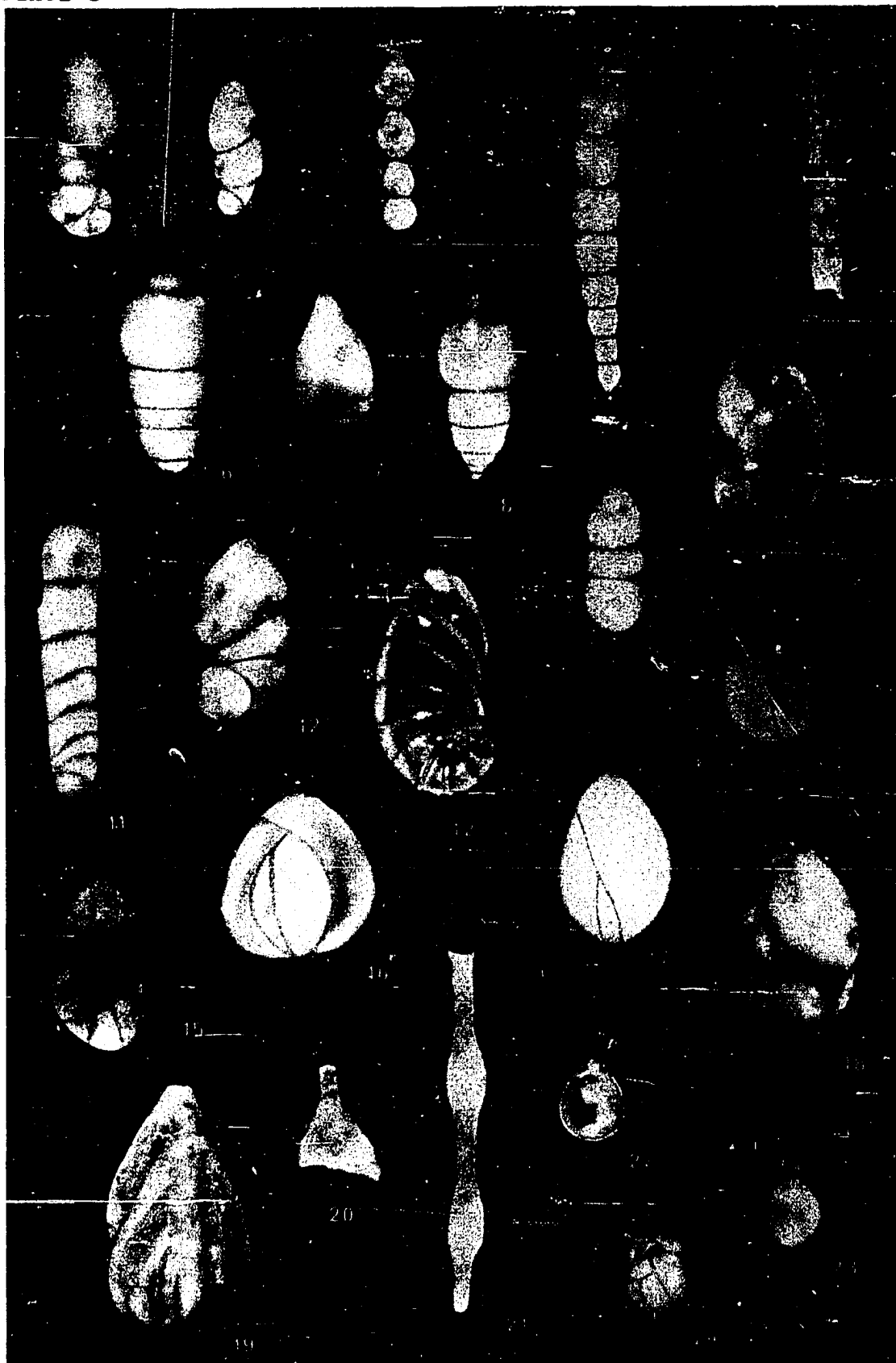
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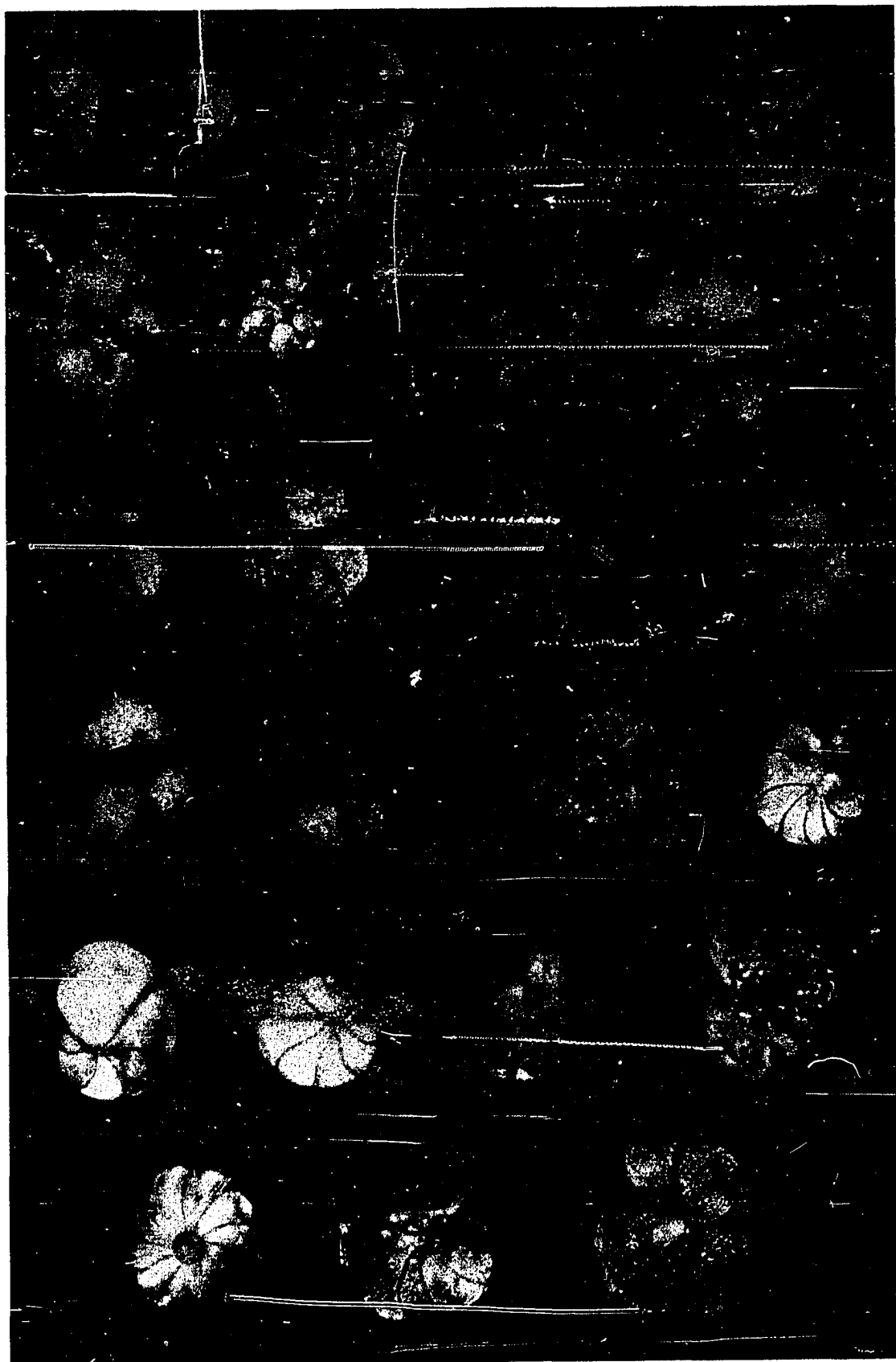
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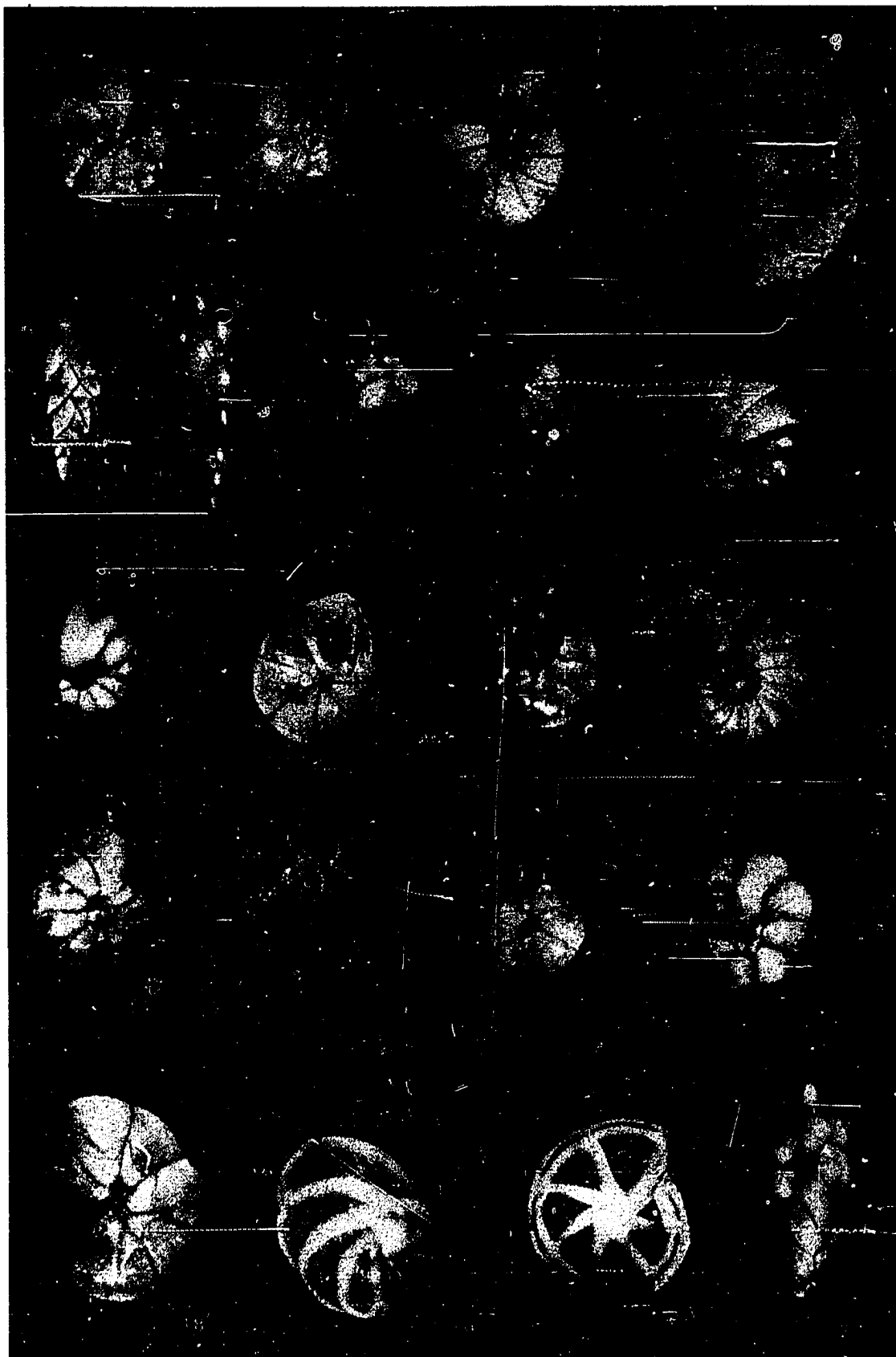


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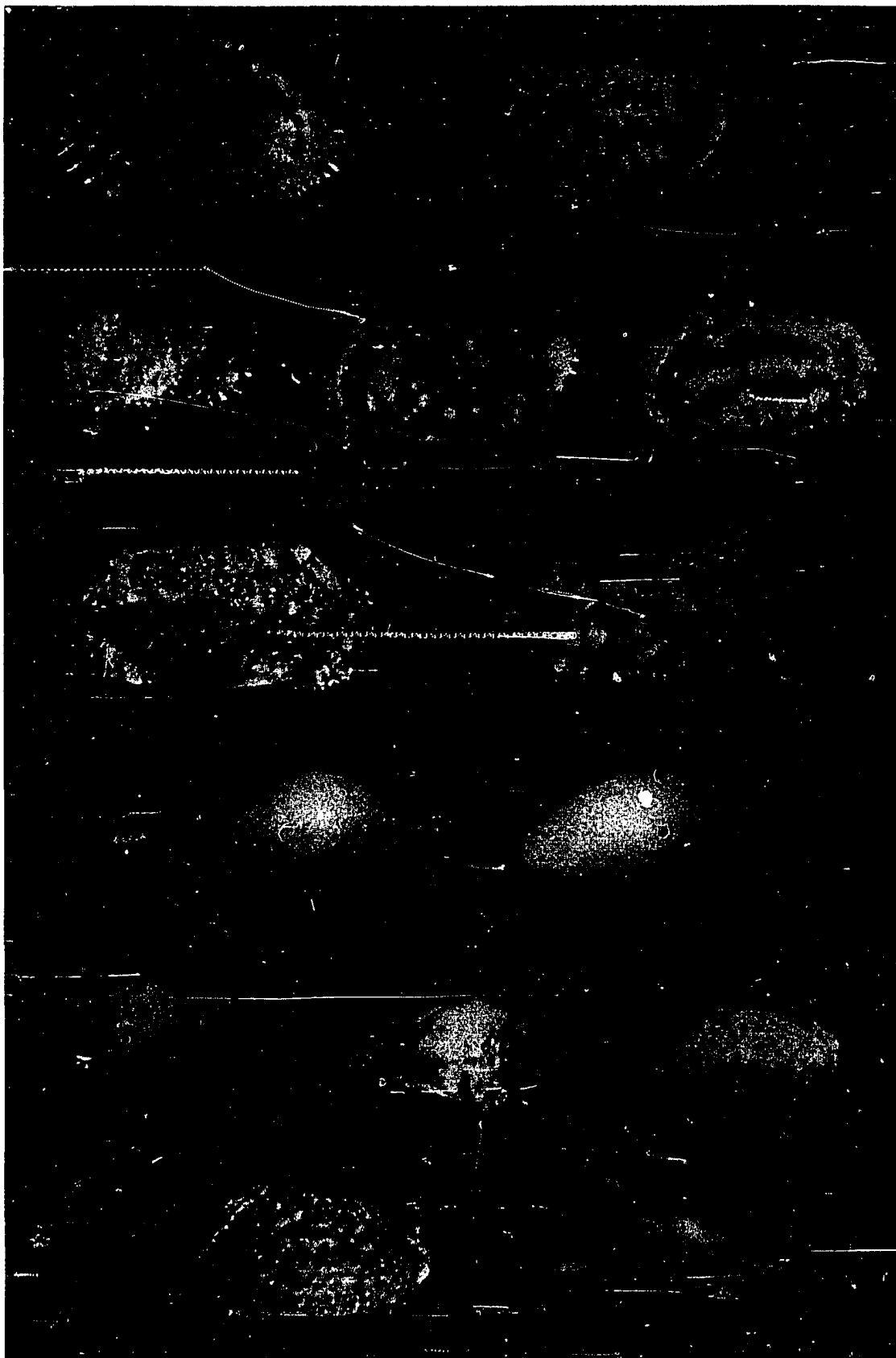


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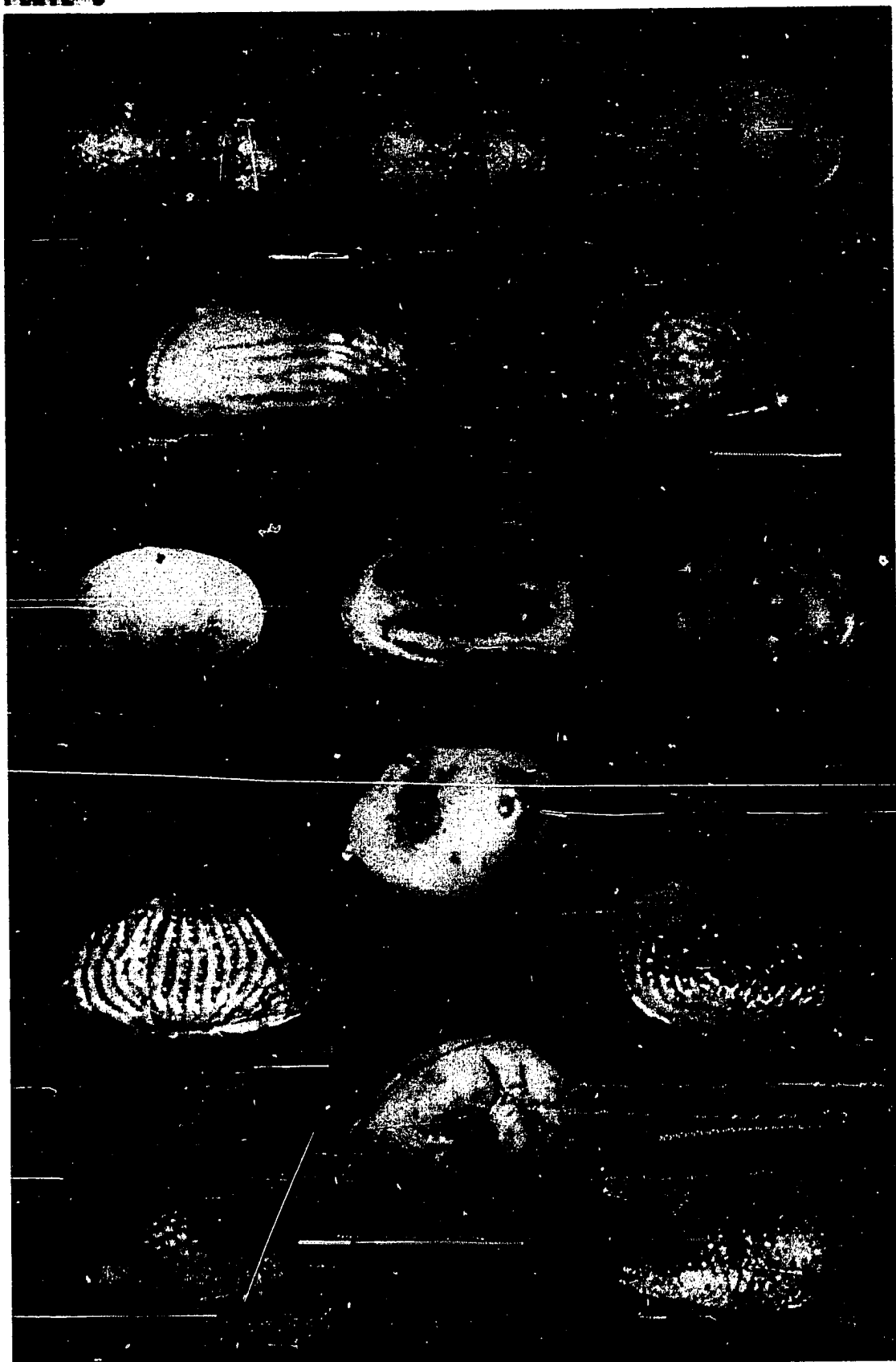
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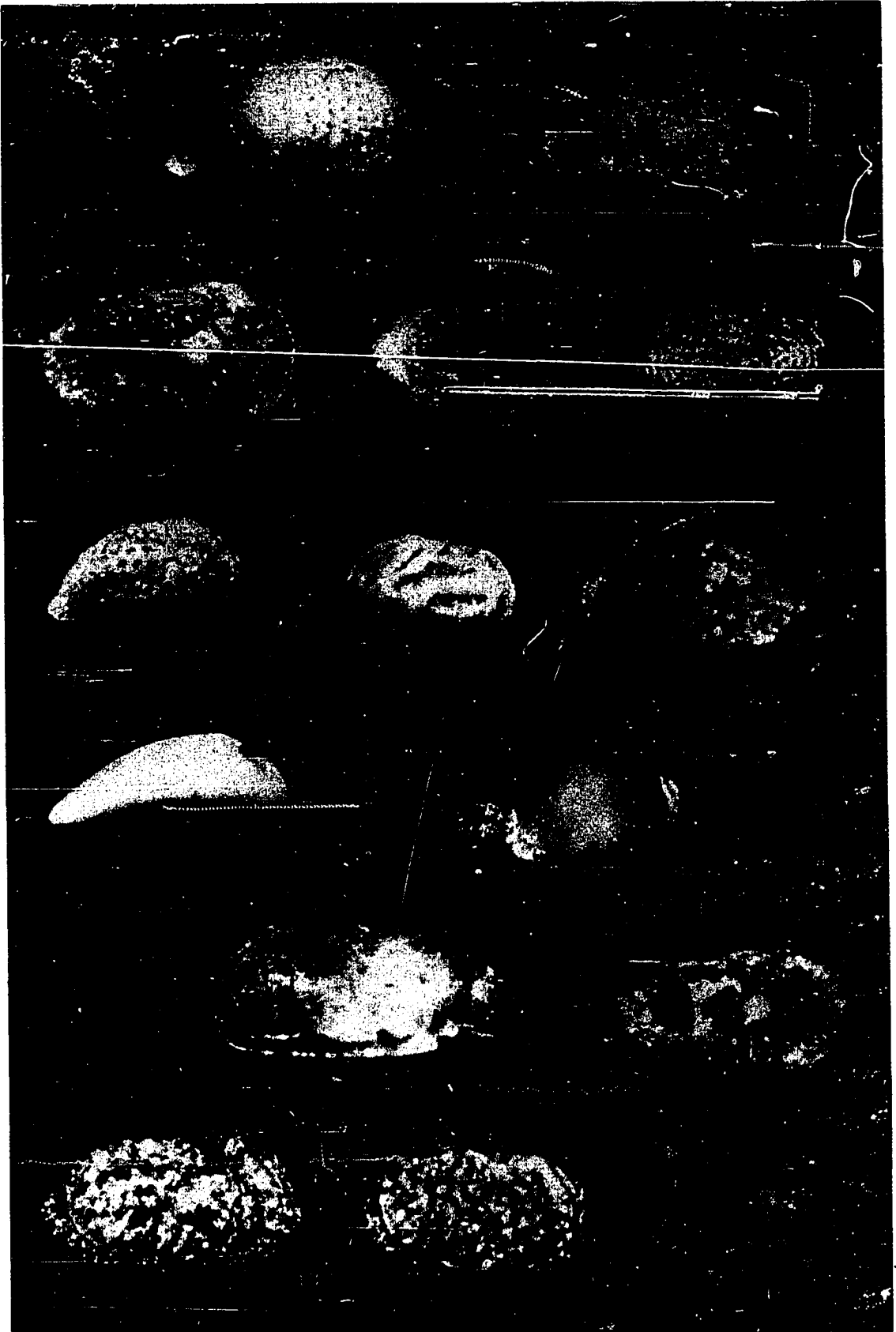
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## VITA

Haeung "Tom" Choung was born in Seoul Korea on February 16, 1942, as a first son of Mr. Yun J. Choung and Mrs. Young S. Choung, both school teachers at the time. After graduating from Kyung Boek high school in 1960, he entered the Seoul University majoring in geology. His college education was briefly interrupted by military service in the Korean Army as a non-commissioned officer between 1963 and 1965. Subsequently, he earned B.S. degree in geology in 1967 and took temporary employment with the Korea Geological Survey until he resumed his graduate study toward the Master's degree at the University of Connecticut in the fall of 1968. Upon completion of M.S. degree in geology, he entered Louisiana State University for his final degree, which he completed in May, 1975. While he was in graduate school, he served as a teaching and research assistant and since August, 1974, he has been employed with Texaco Inc. as a petroleum geologist.



## EXAMINATION AND THESIS REPORT

Candidate: Haeung Choung

Major Field: Geology

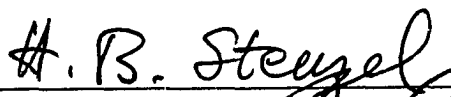
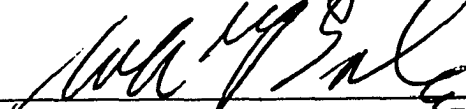
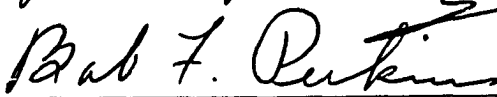
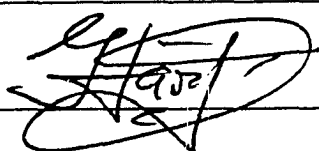
Title of Thesis: Paleocology, Stratigraphy, and Taxonomy of the Foraminifera of the Weches Formation of East Texas and the Cane River Formation of Louisiana.

Approved:

  
Major Professor and Chairman

  
Dean of the Graduate School

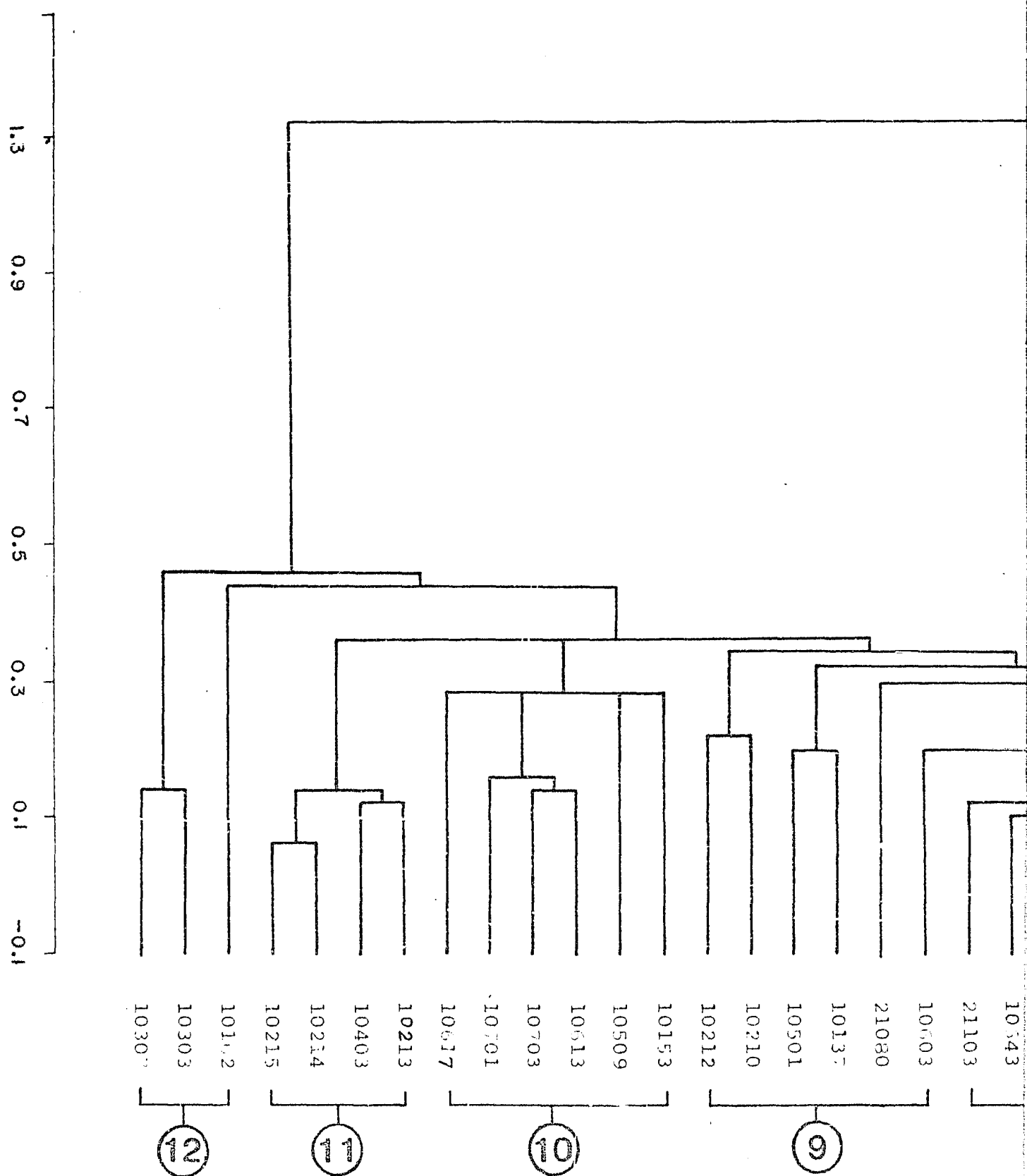
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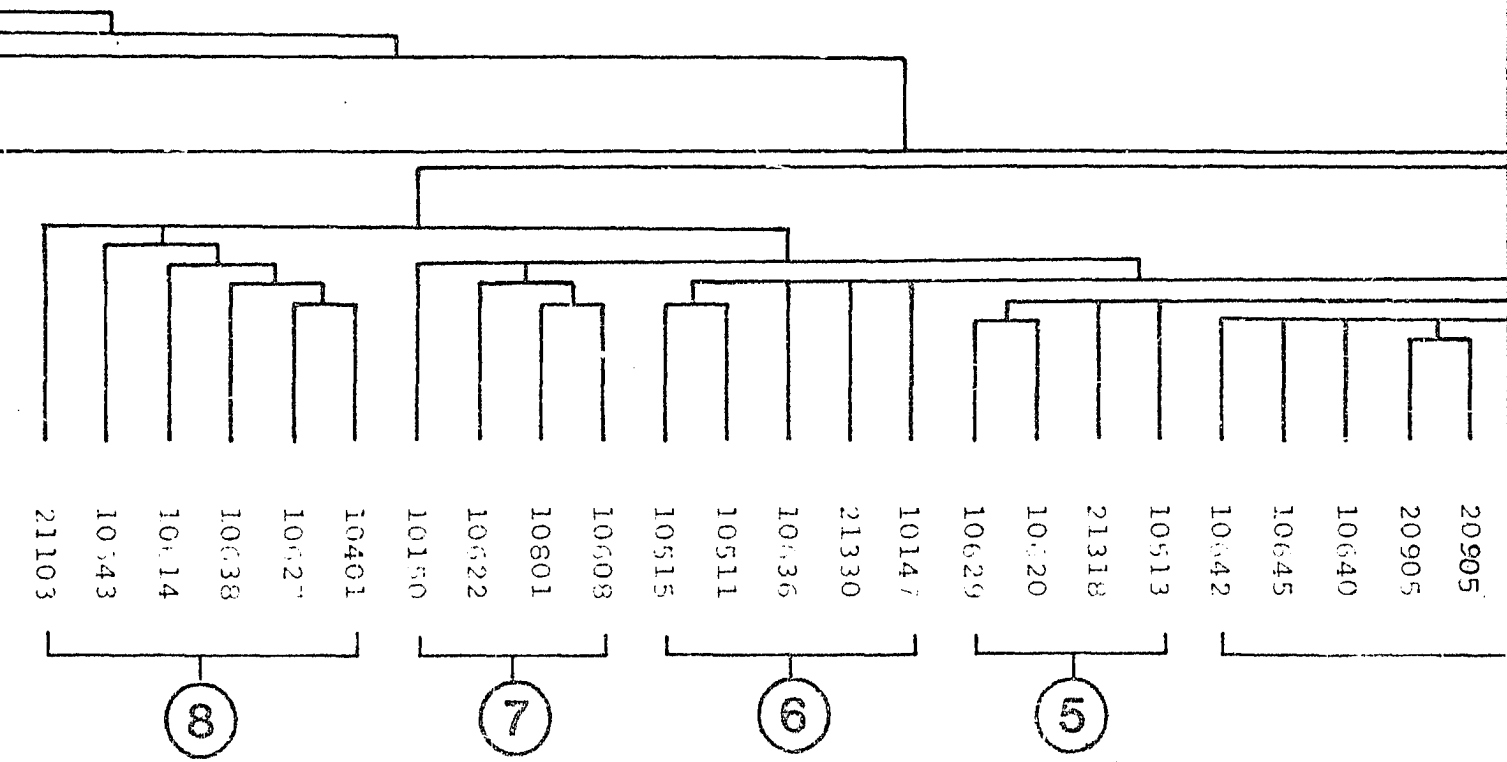
Date of Examination:

November 26, 1974

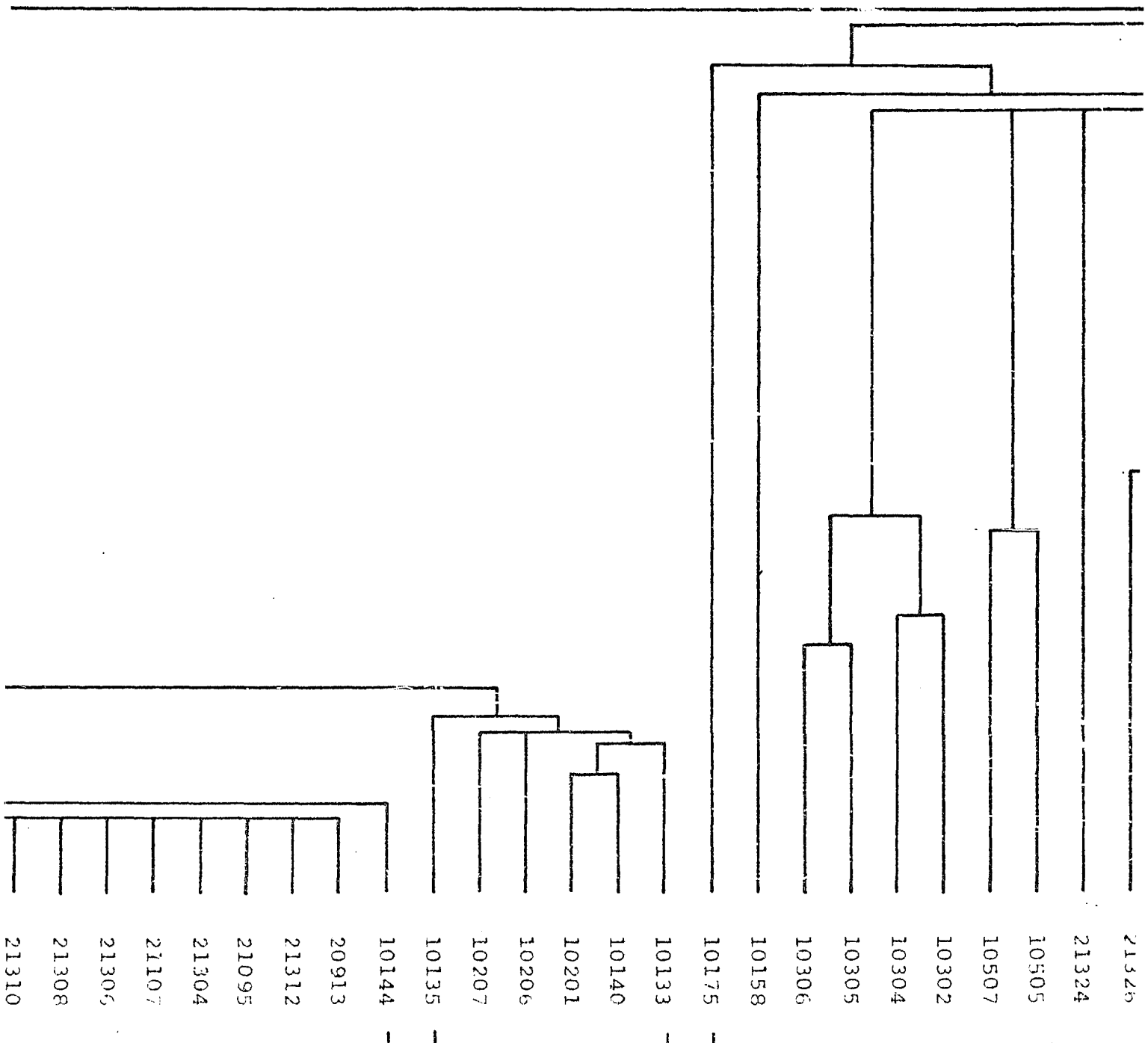
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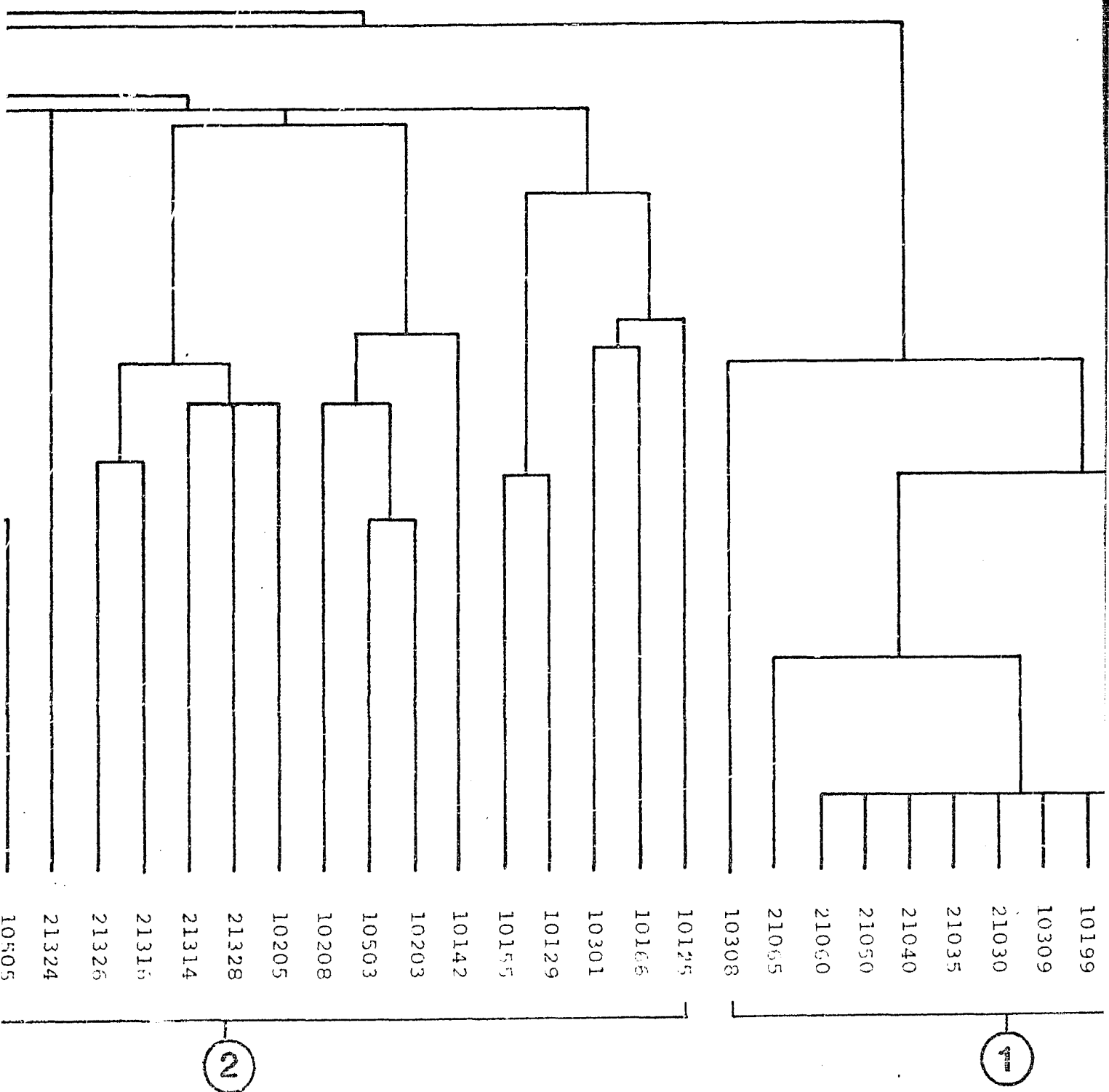


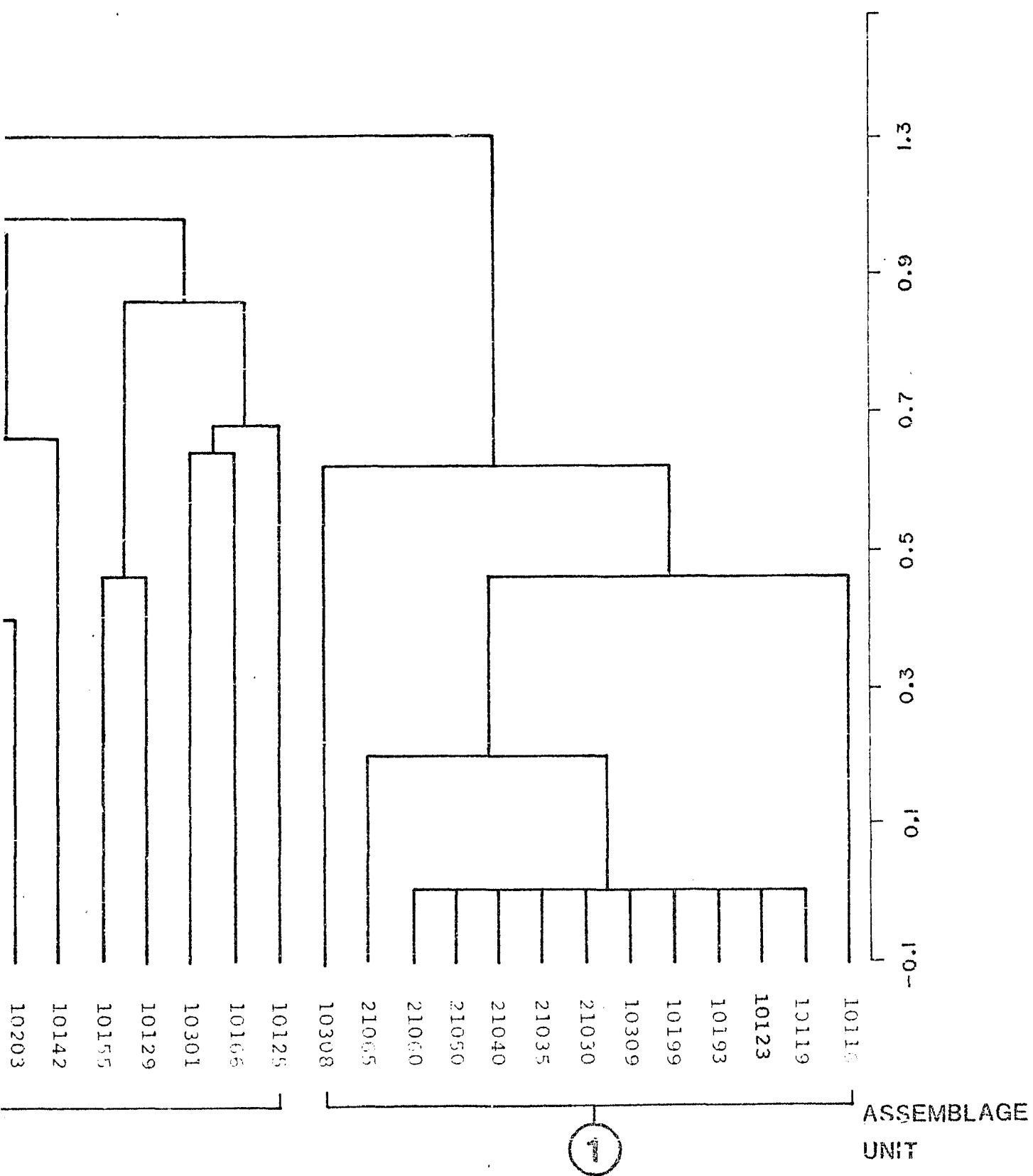
RAL ASSEMBLAGES











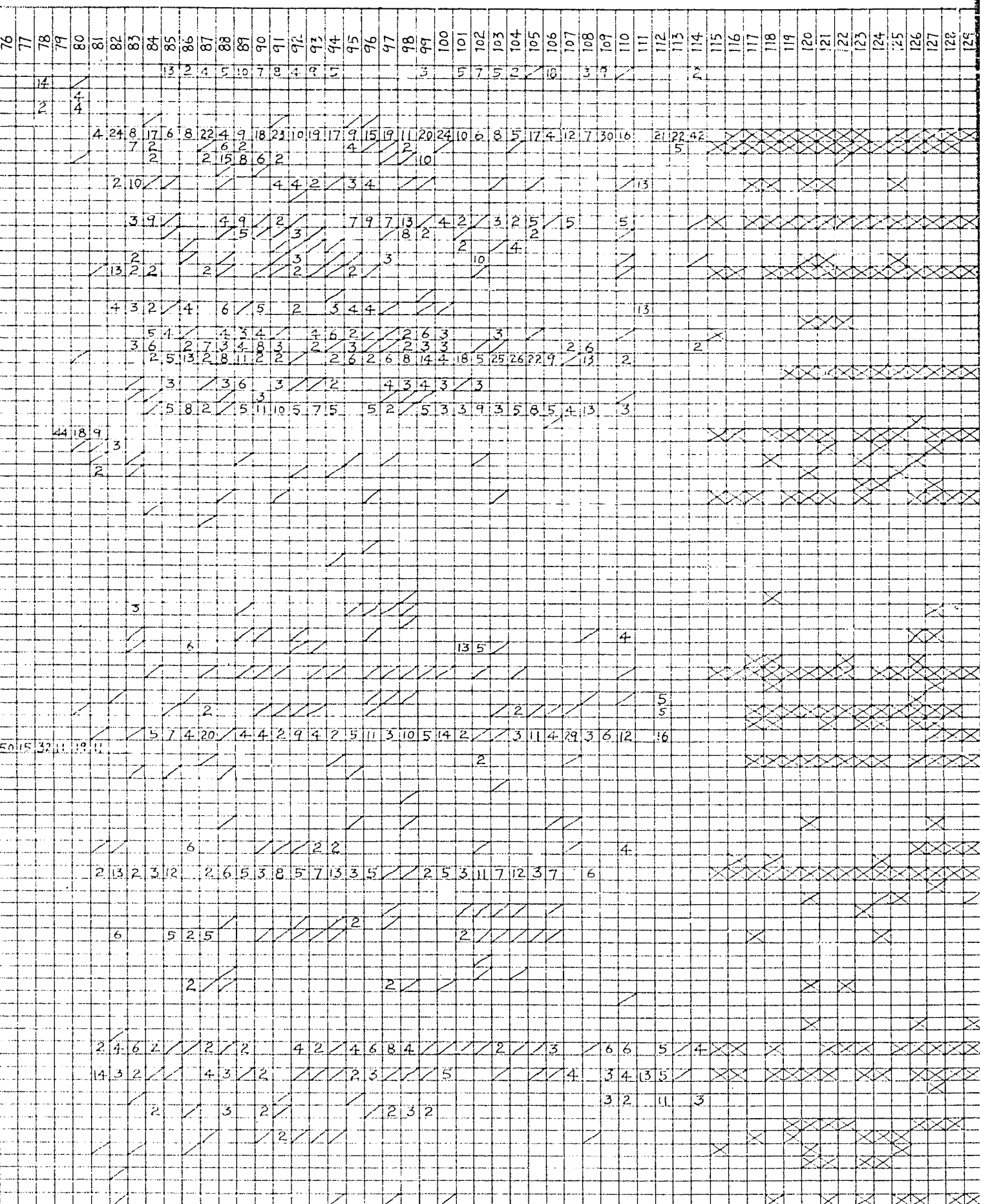
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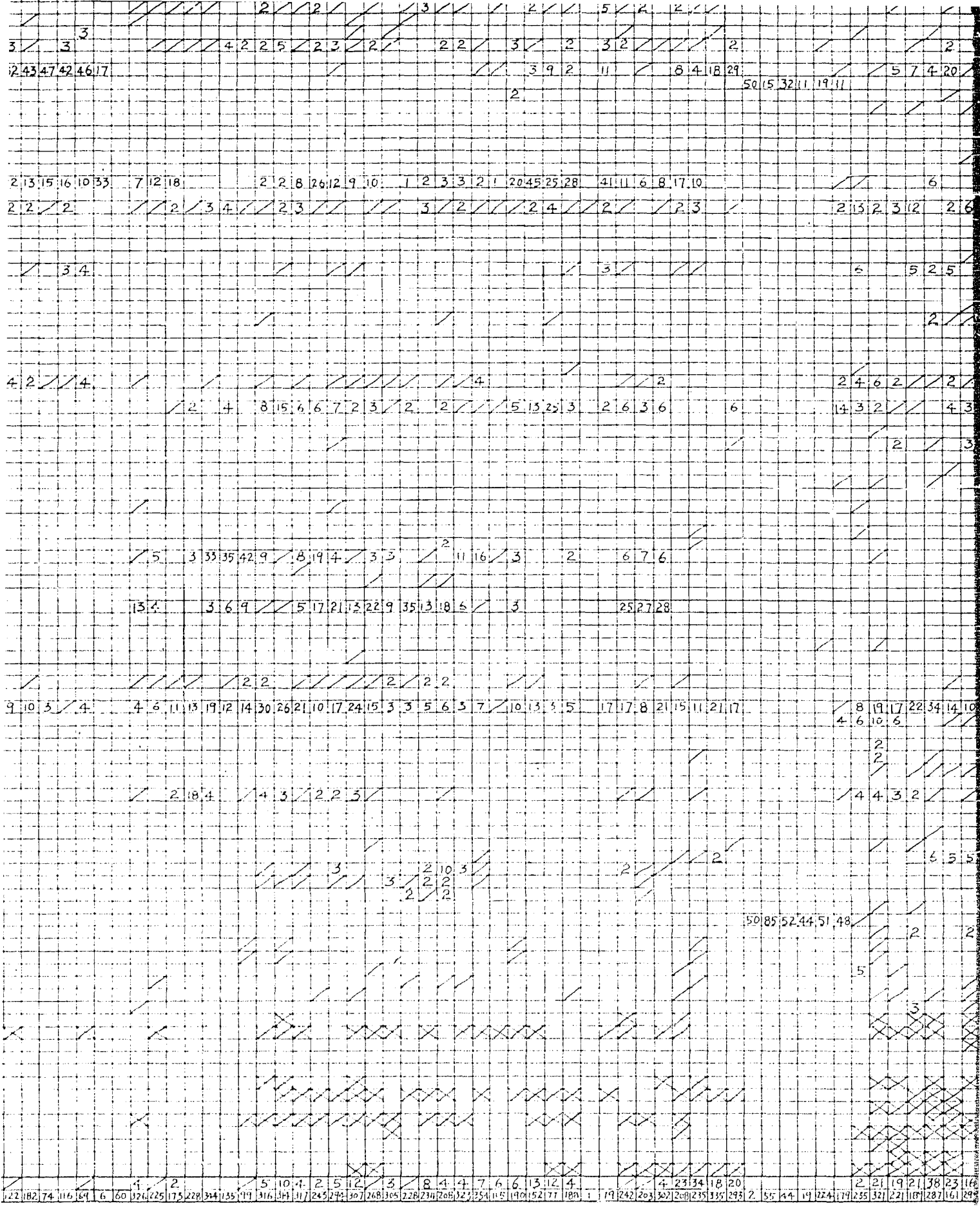
AMINIFERA

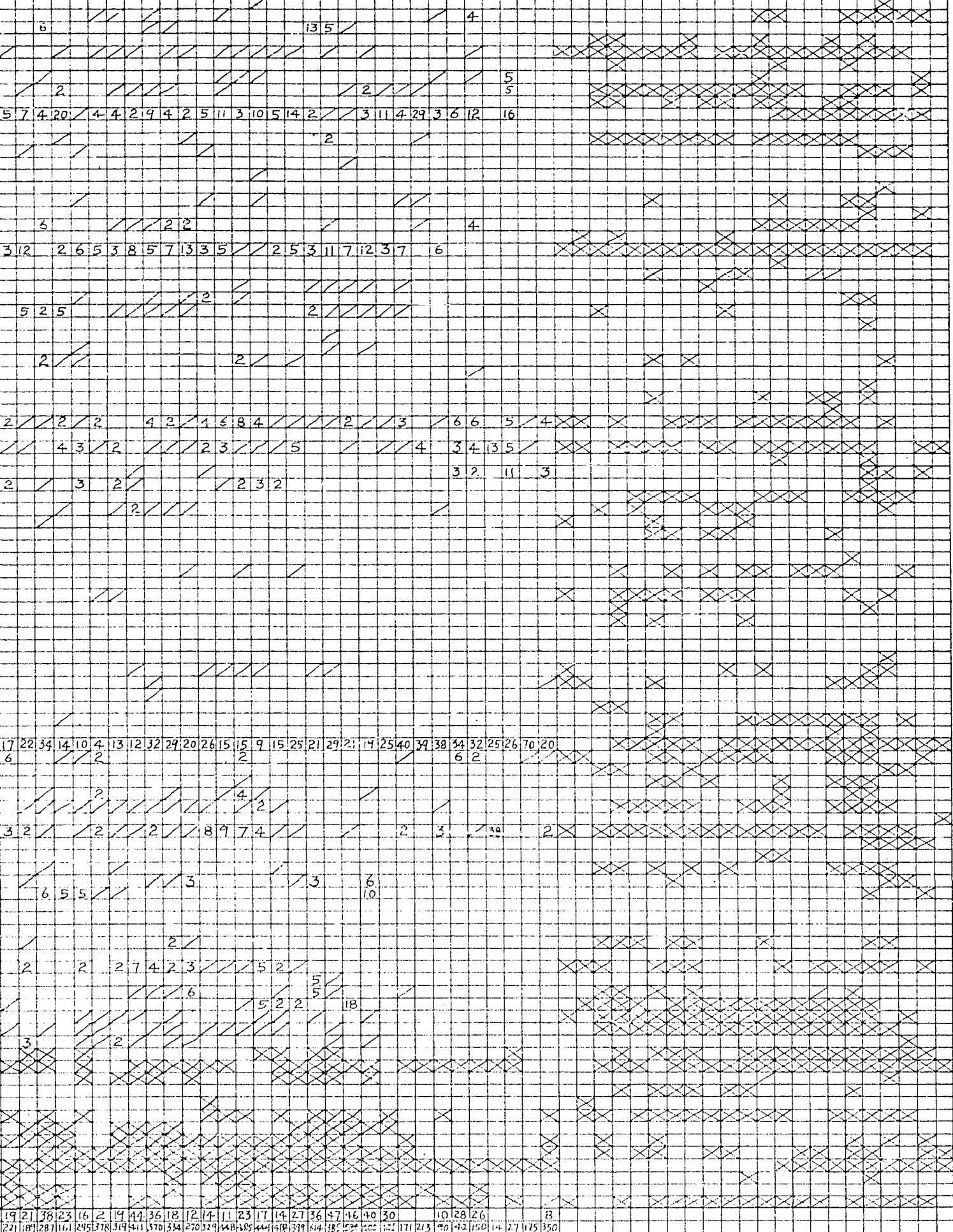






X = PRESENT (NON-QUANTITATIVE SAMPLE)







## APPENDIX VI. (B) OSTRACODA, MOLLUSCA, BRYOZOA, AND ANTHOZOA

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/ = PRESENT

